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(54) **PARTICLE DELIVERY SYSTEM OF AN AGRICULTURAL ROW UNIT**

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CPC .. A01C 7/20; A01C 7/042; A01C 7/00; A01C 7/04; A01C 7/122; A01C 7/121; A01C 7/12; A01C 7/08

See application file for complete search history.

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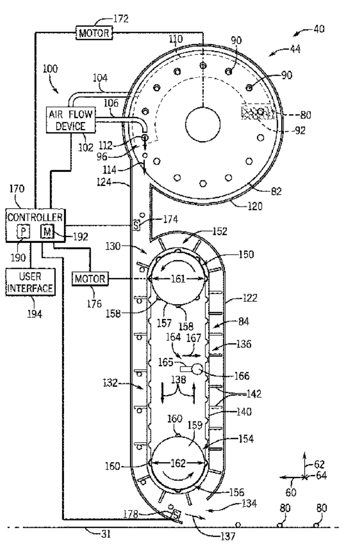
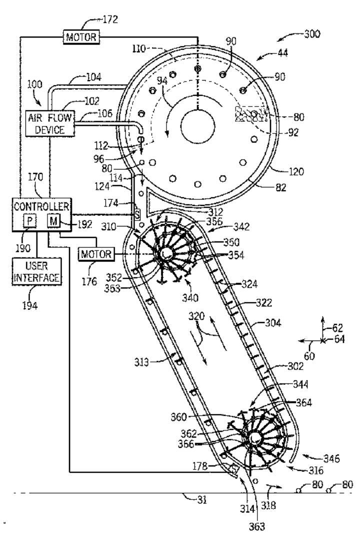
(57) **ABSTRACT**

A particle delivery system of an agricultural row unit includes a particle belt having a particle acceleration section. The particle belt is configured to receive a particle, to accelerate the particle at the particle acceleration section, and to expel the particle toward a trench in soil. The particle delivery system includes a first hub assembly engaged with the particle belt at a first location and a second hub assembly engaged with the particle belt at a second location. The particle acceleration section is disposed generally at the first location, a substantially no-slip condition exists between the first hub assembly and the particle belt at the first location and between the second hub assembly and the particle belt at the second location, and the first hub assembly and the second hub assembly are configured to stretch the particle belt at the particle acceleration section to accelerate the particle.

20 Claims, 10 Drawing Sheets





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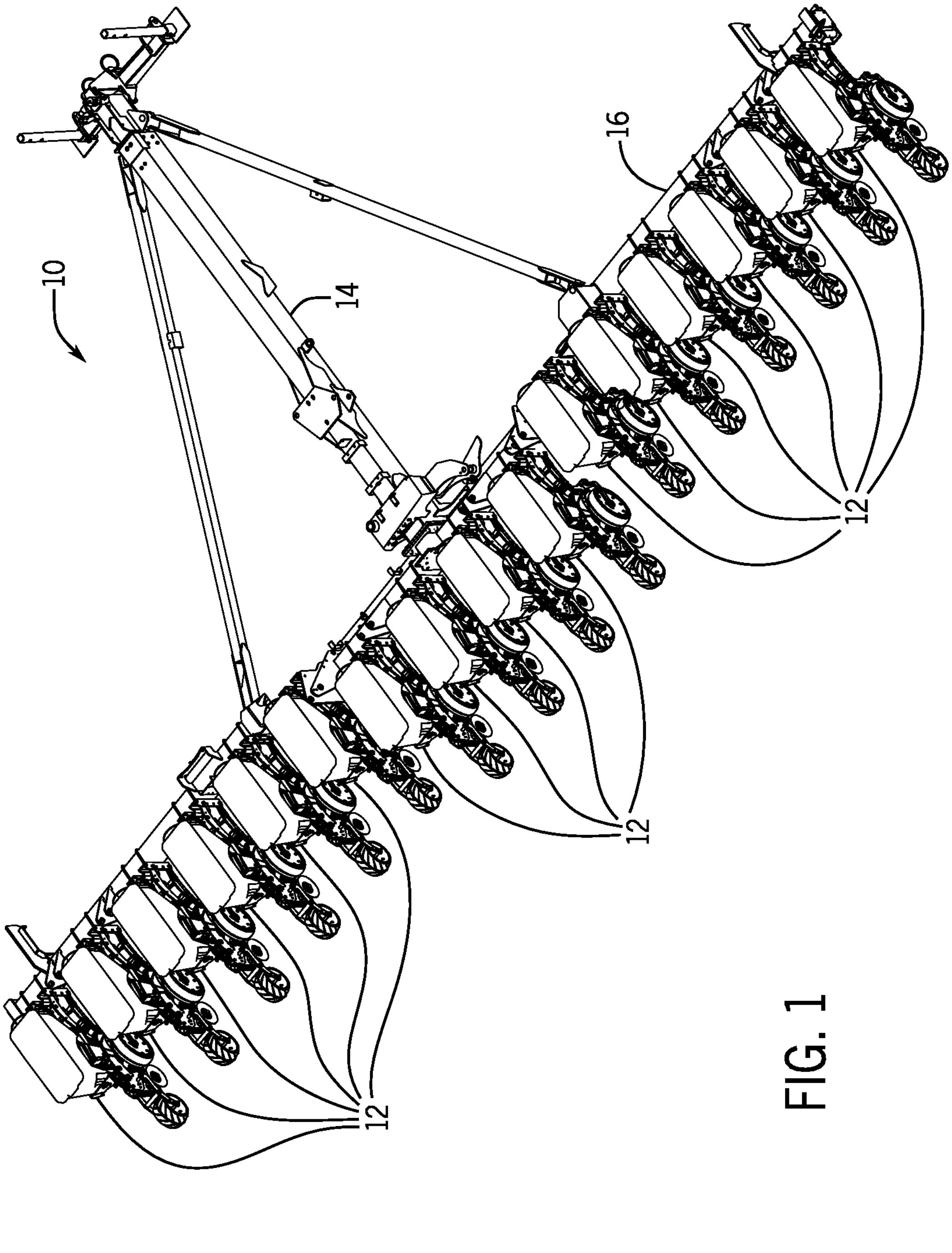

FIG. 1

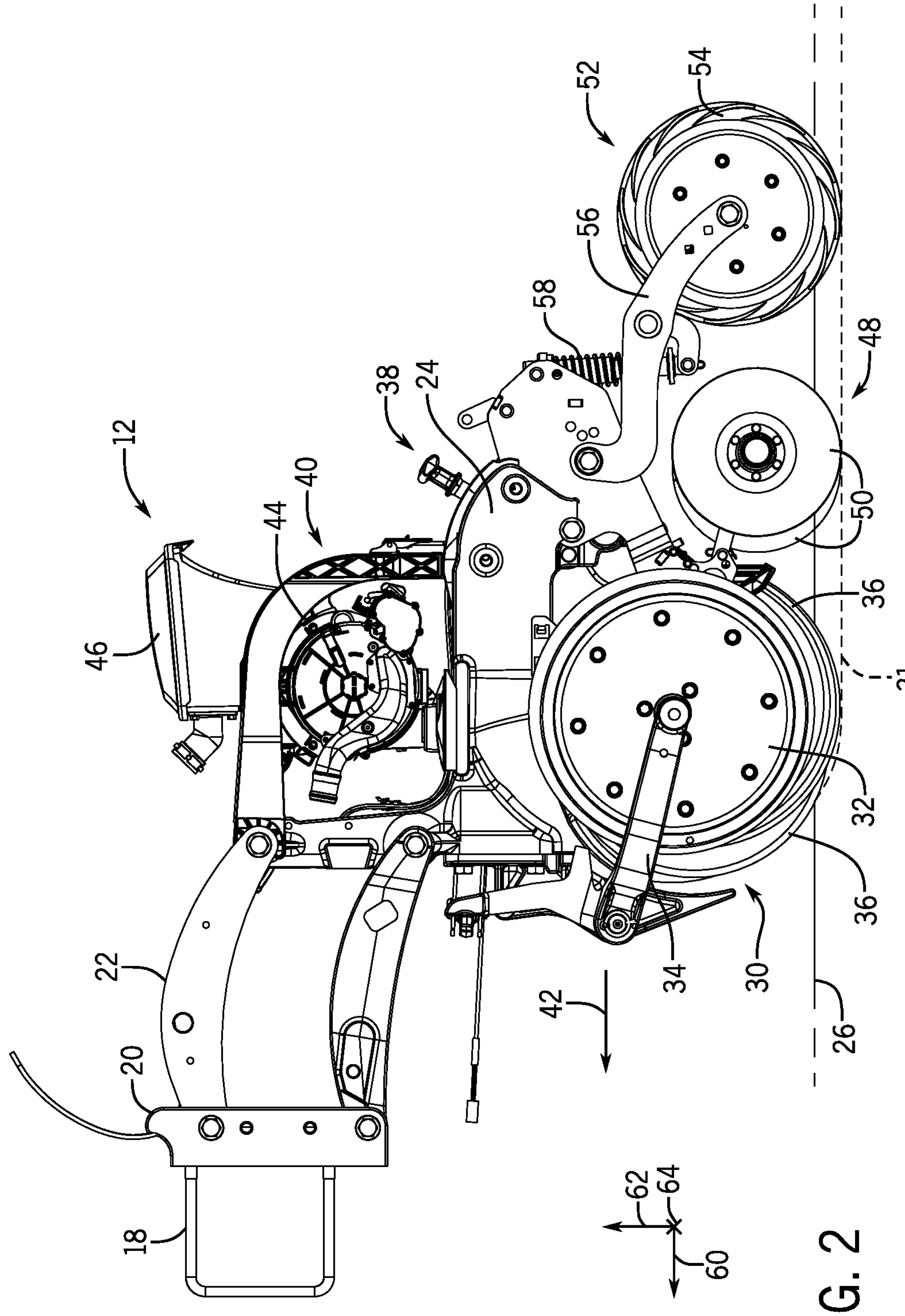
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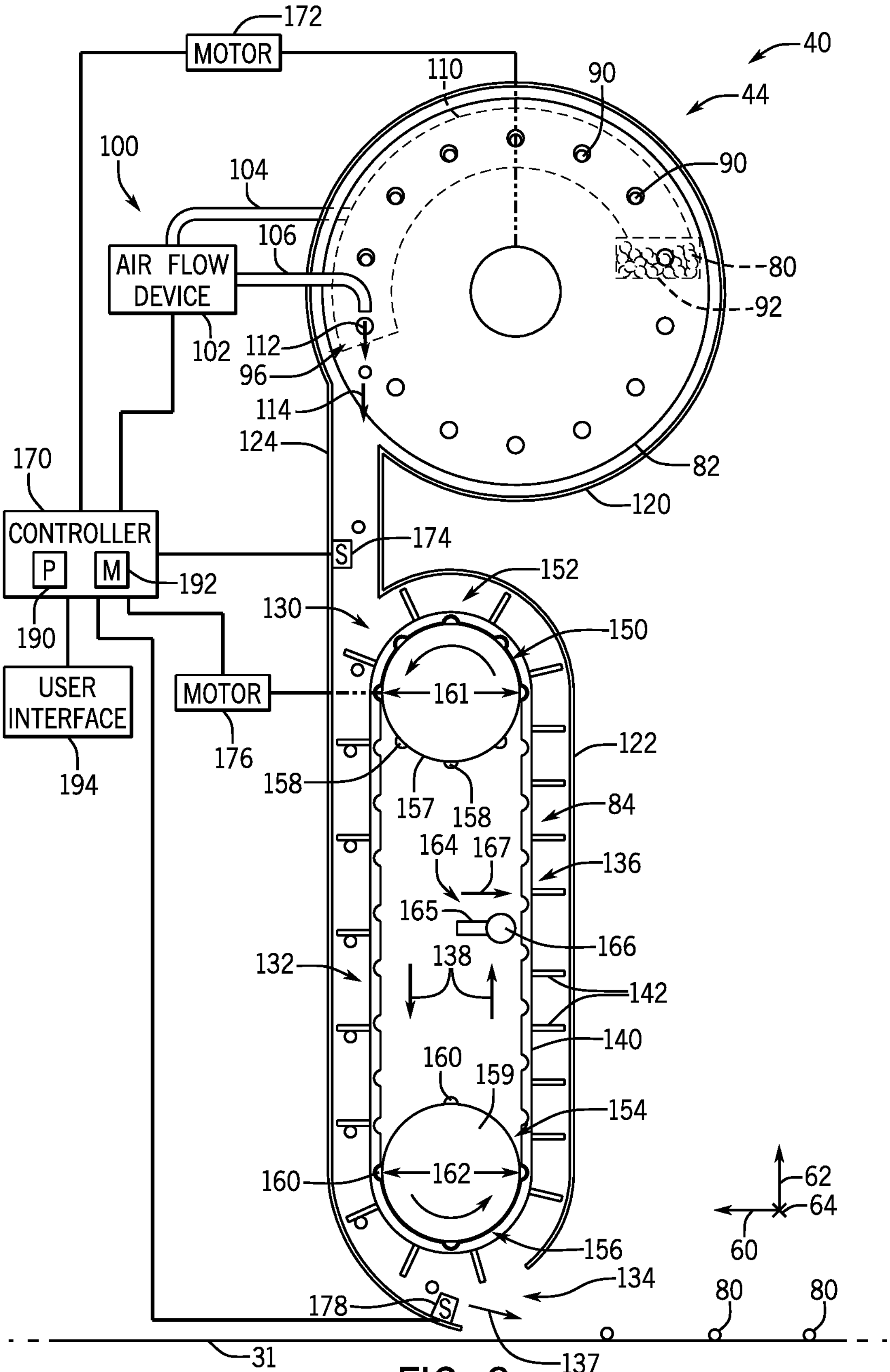
FIG. 2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CONTROLLER
P
M
S
174
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150
USER INTERFACE
MOTOR
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FIG. 3

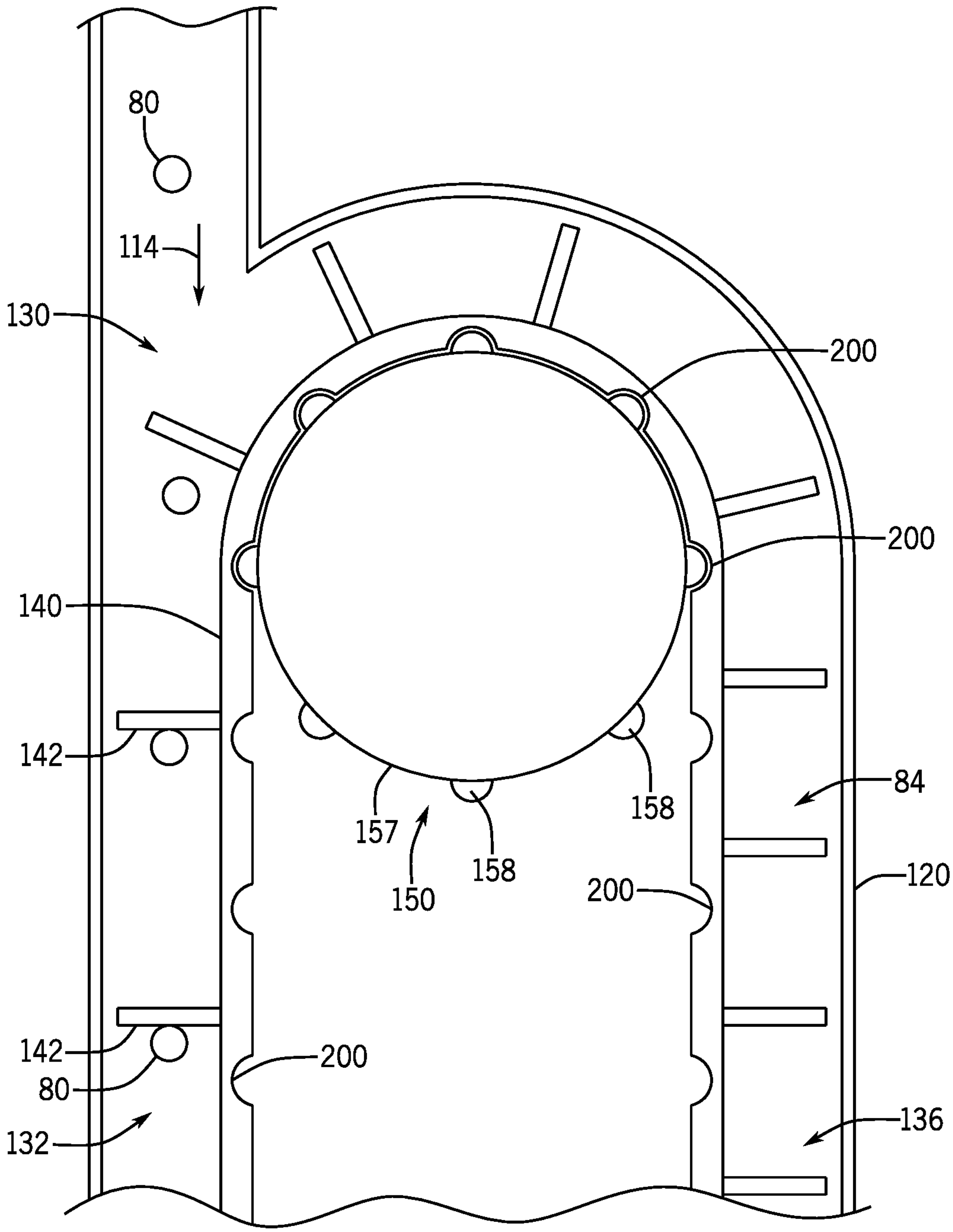
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FIG. 4

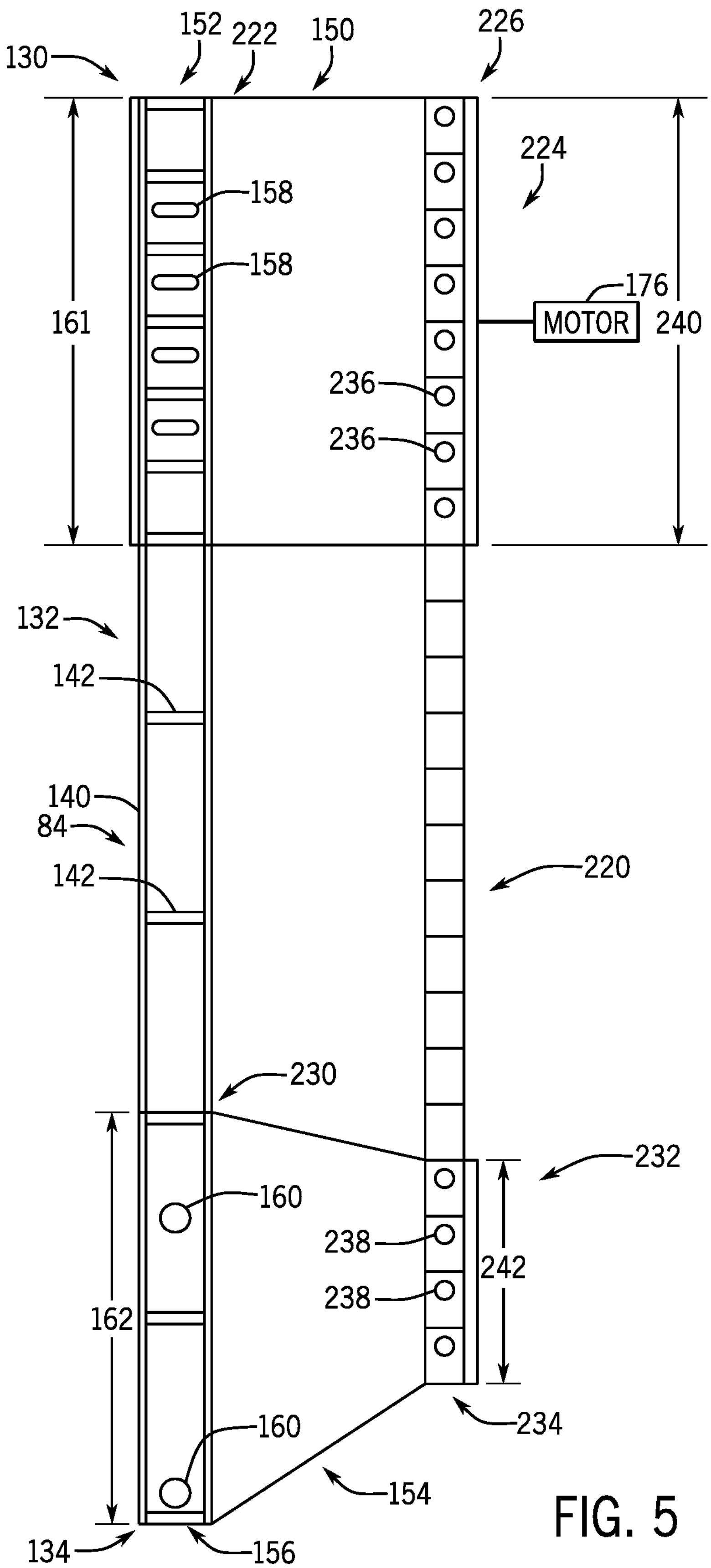
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FIG. 5

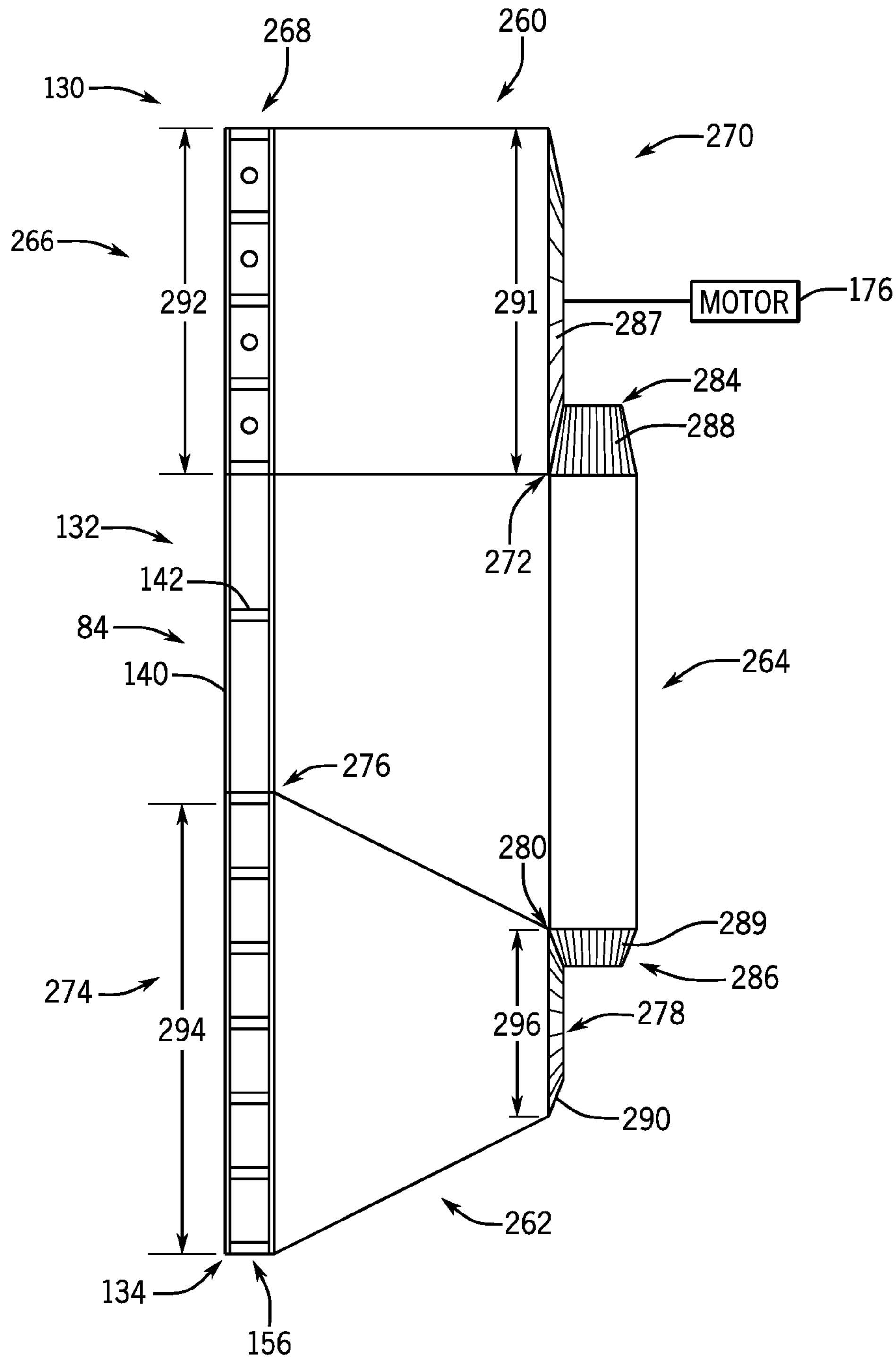
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FIG. 6

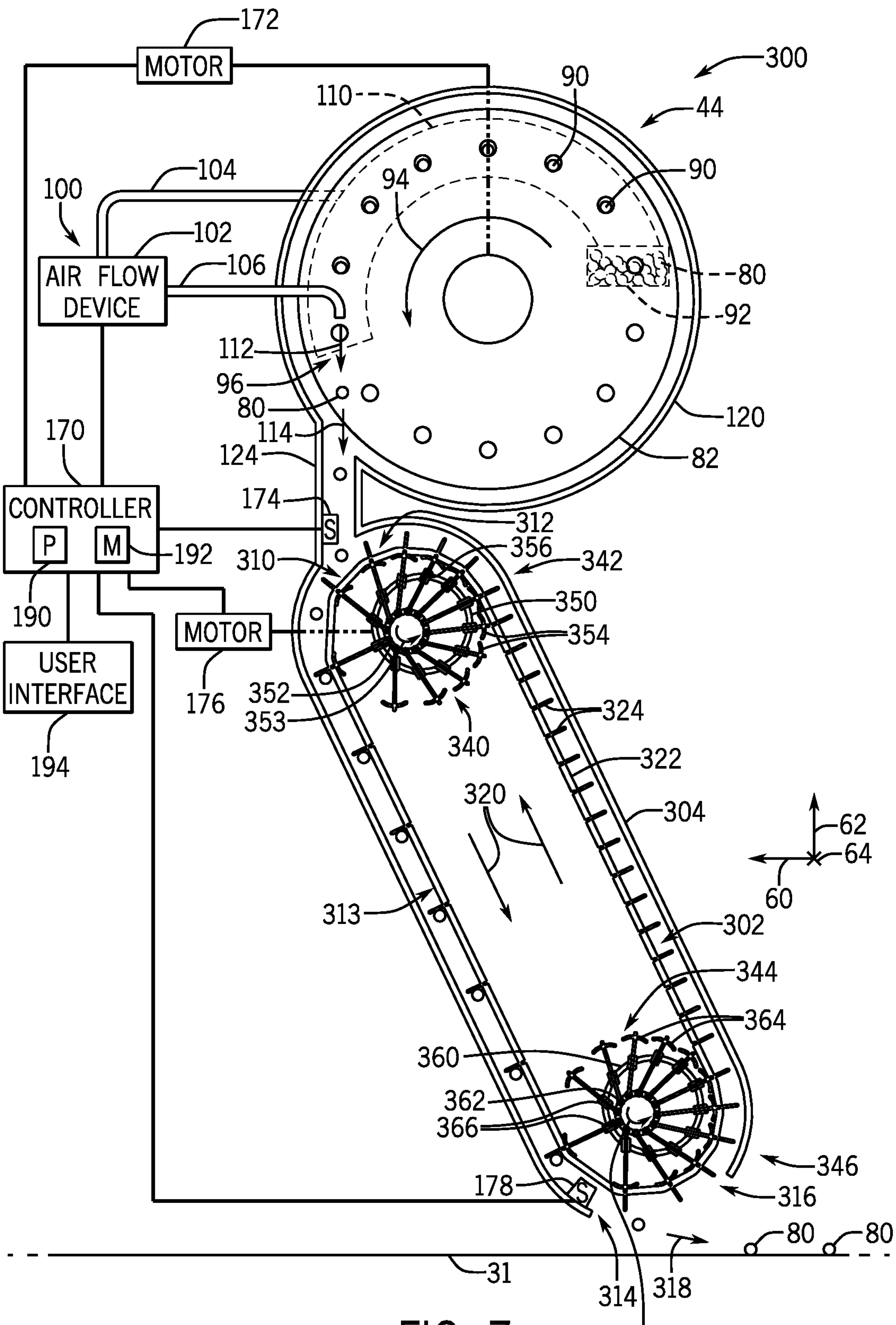

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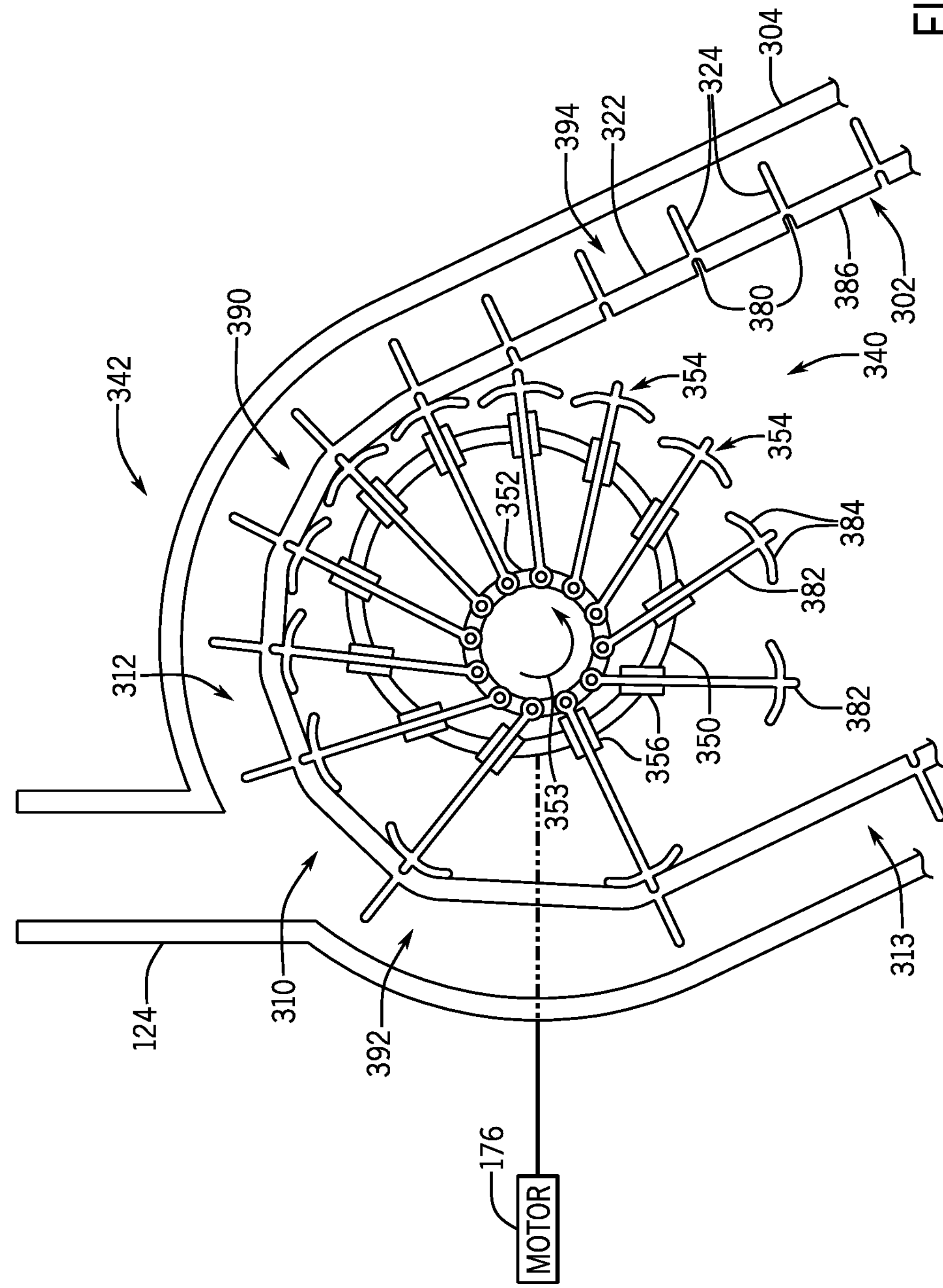
FIG. 7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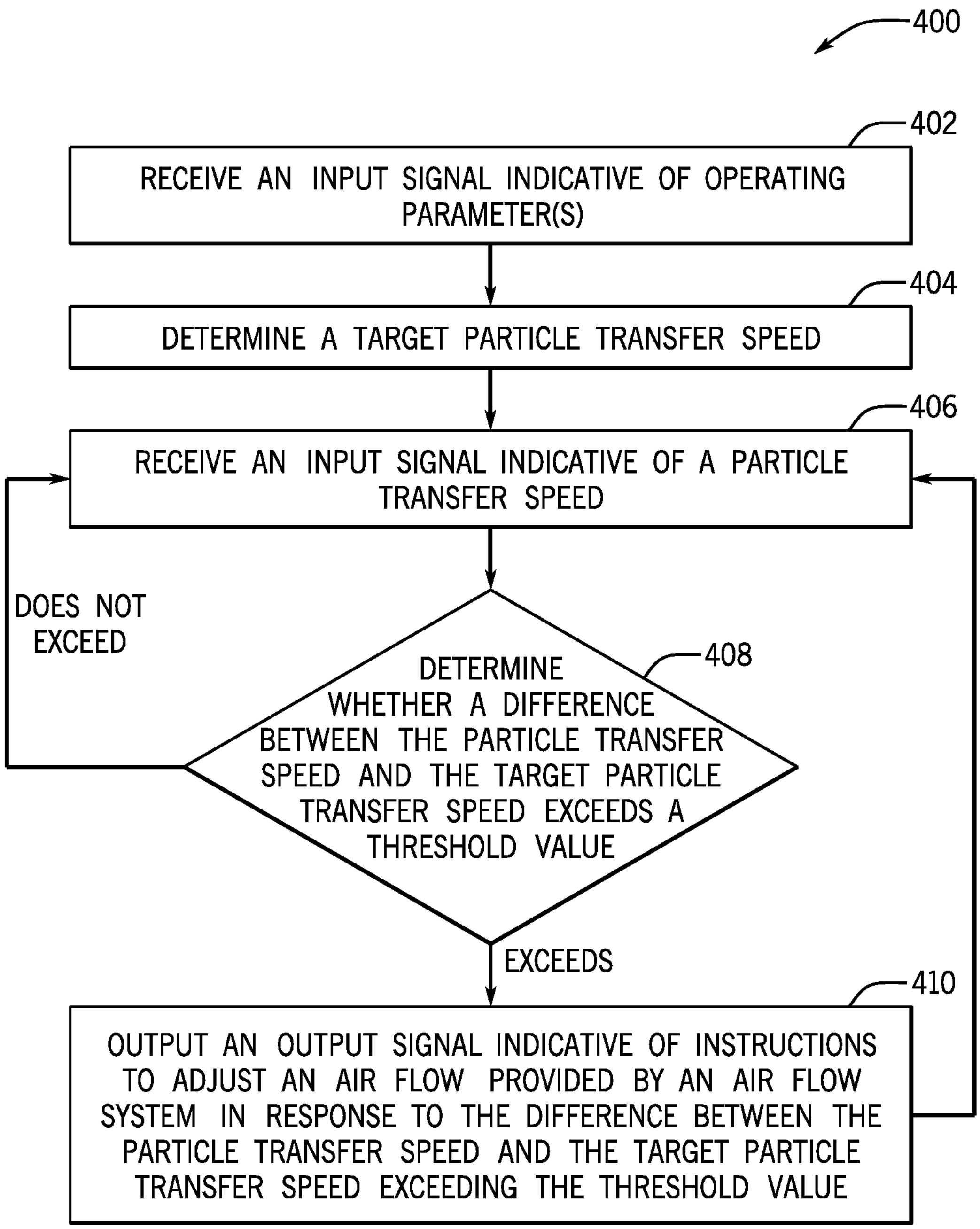
MOTOR

FIG. 8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DETERMINE A TARGET PARTICLE TRANSFER SPEED
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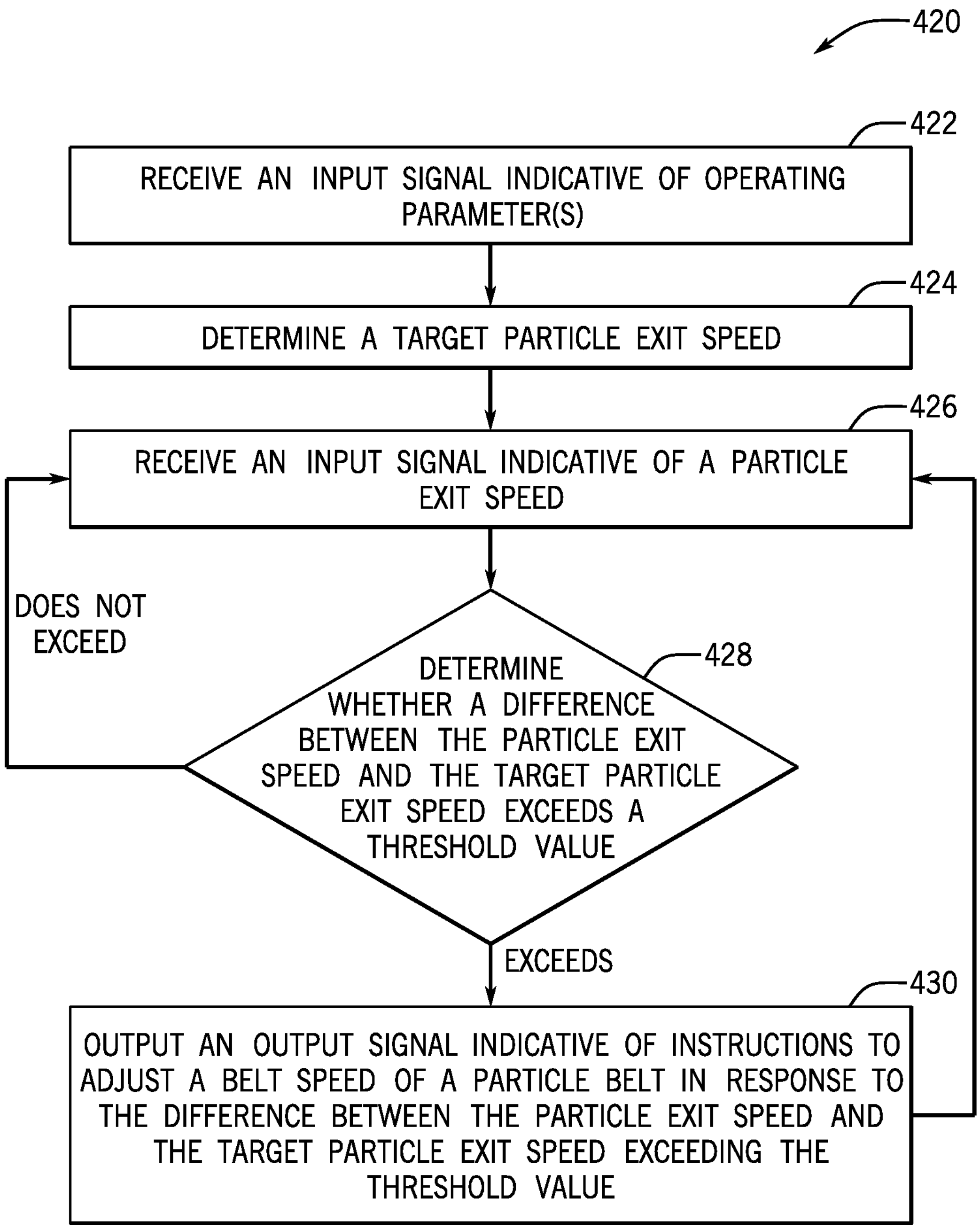
RECEIVE AN INPUT SIGNAL INDICATIVE OF A PARTICLE TRANSFER SPEED
DOES NOT EXCEED
408
DETERMINE WHETHER A DIFFERENCE BETWEEN THE PARTICLE TRANSFER SPEED AND THE TARGET PARTICLE TRANSFER SPEED EXCEEDS A THRESHOLD VALUE
EXCEEDS
410
OUTPUT AN OUTPUT SIGNAL INDICATIVE OF INSTRUCTIONS TO ADJUST AN AIR FLOW PROVIDED BY AN AIR FLOW SYSTEM IN RESPONSE TO THE DIFFERENCE BETWEEN THE PARTICLE TRANSFER SPEED AND THE TARGET PARTICLE TRANSFER SPEED EXCEEDING THE THRESHOLD VALUE

FIG. 9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DETERMINE A TARGET PARTICLE EXIT SPEED
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RECEIVE AN INPUT SIGNAL INDICATIVE OF A PARTICLE EXIT SPEED
DOES NOT EXCEED
428
DETERMINE WHETHER A DIFFERENCE BETWEEN THE PARTICLE EXIT SPEED AND THE TARGET PARTICLE EXIT SPEED EXCEEDS A THRESHOLD VALUE
EXCEEDS
430
OUTPUT AN OUTPUT SIGNAL INDICATIVE OF INSTRUCTIONS TO ADJUST A BELT SPEED OF A PARTICLE BELT IN RESPONSE TO THE DIFFERENCE BETWEEN THE PARTICLE EXIT SPEED AND THE TARGET PARTICLE EXIT SPEED EXCEEDING THE THRESHOLD VALUE

FIG. 10

PARTICLE DELIVERY SYSTEM OF AN AGRICULTURAL ROW UNIT

BACKGROUND

The present disclosure relates generally to a particle delivery system of an agricultural row unit.

Generally, planting implements (e.g., planters) are towed behind a tractor or other work vehicle via a mounting bracket secured to a rigid frame of the implement. Planting implements typically include multiple row units distributed across a width of the implement. Each row unit is configured to deposit seeds at a desired depth beneath the soil surface of a field, thereby establishing rows of planted seeds. For example, each row unit typically includes a ground engaging tool or opener that forms a seeding path (e.g., trench) for seed deposition into the soil. An agricultural product delivery system (e.g., including a metering system and a seed tube) is configured to deposit seeds and/or other agricultural products (e.g., fertilizer) into the trench. The opener/agricultural product delivery system is followed by closing discs that move displaced soil back into the trench and/or a packer wheel that packs the soil on top of the deposited seeds/other agricultural products.

Certain row units, or planting implements generally, include a seed storage area configured to store the seeds. The agricultural product delivery system is configured to transfer the seeds from the seed storage area into the trench. For example, the agricultural product delivery system may include a metering system that meters the seeds from the seed storage area into a seed tube for subsequent delivery to the trench. Certain types of seeds may benefit from a particular spacing along the trench. Additionally, the planting implement having the row units may travel at varying speeds based on the type of seed being deposited into the soil, the type and structure of the soil within the field, and other factors. Typically, the row units output the seeds to the trench at the speed that the implement is traveling through the field, which may affect the spacing between the seeds and may cause the seeds to be deposited at locations along the trench other than target locations (e.g., outside the target locations).

BRIEF DESCRIPTION

Certain embodiments commensurate in scope with the disclosed subject matter are summarized below. These embodiments are not intended to limit the scope of the disclosure, but rather these embodiments are intended only to provide a brief summary of certain disclosed embodiments. Indeed, the present disclosure may encompass a variety of forms that may be similar to or different from the embodiments set forth below.

In certain embodiments, a particle delivery system of an agricultural row unit includes a particle belt having a particle acceleration section. The particle belt is configured to receive a particle, to accelerate the particle at the particle acceleration section, and to expel the particle toward a trench in soil. The particle delivery system includes a first hub assembly engaged with the particle belt at a first location and a second hub assembly engaged with the particle belt at a second location. The particle acceleration section is disposed generally at the first location, a substantially no-slip condition exists between the first hub assembly and the particle belt at the first location and between the second hub assembly and the particle belt at the second location, and the first hub assembly and the second hub assembly are configured to stretch the particle belt at the particle acceleration section to accelerate the particle.

DRAWINGS

These and other features, aspects, and advantages of the present disclosure will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

FIG. **1** is a perspective view of an embodiment of an agricultural implement having multiple row units distributed across a width of the agricultural implement, in accordance with an aspect of the present disclosure;

FIG. **2** is a side view of an embodiment of a row unit that may be employed on the agricultural implement of FIG. **1**, in accordance with an aspect of the present disclosure;

FIG. **3** is a side view of an embodiment of a particle delivery system that may be employed within the row unit of FIG. **2**, in accordance with an aspect of the present disclosure;

FIG. **4** is a side view of an embodiment a particle belt and a wheel of a particle delivery system that may be employed within the row unit of FIG. **2**, in accordance with an aspect of the present disclosure;

FIG. **5** is a rear view of an embodiment of a particle belt and wheels of a particle delivery system that may be employed within the row unit of FIG. **2**, in accordance with an aspect of the present disclosure;

FIG. **6** is a rear view of another embodiment of a particle belt and wheels of a particle delivery system that may be employed within the row unit of FIG. **2**, in accordance with an aspect of the present disclosure;

FIG. **7** is a side view of another embodiment of a particle delivery system that may be employed within the row unit of FIG. **2**, in accordance with an aspect of the present disclosure;

FIG. **8** is a side view of an embodiment a particle belt and a hub assembly of a particle delivery system that may be employed within the row unit of FIG. **2**, in accordance with an aspect of the present disclosure;

FIG. **9** is a flow diagram of an embodiment of a process for controlling a particle delivery system, in accordance with an aspect of the present disclosure; and

FIG. **10** is a flow diagram of an embodiment of a process for controlling a particle delivery system, in accordance with an aspect of the present disclosure.

DETAILED DESCRIPTION

One or more specific embodiments of the present disclosure will be described below. In an effort to provide a concise description of these embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

When introducing elements of various embodiments of the present disclosure, the articles "a," "an," "the," and "said" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements. Any examples of operating parameters and/or environmental conditions are not exclusive of other parameters/conditions of the disclosed embodiments.

Certain embodiments of the present disclosure include a particle delivery system for a row unit of an agricultural implement. Certain agricultural implements include row units configured to deliver particles (e.g., seeds) to trenches in soil. For example, a particle distribution system may transport the particles from a storage tank of the agricultural implement to the row units (e.g., to a hopper assembly of each row unit or directly to a particle delivery system of each row unit), and/or the particles may be delivered from a hopper assembly of each row unit to a respective particle delivery system. Each particle delivery system may output the particles to a respective trench as the agricultural implement travels over the soil. Certain agricultural implements are configured to travel at particular speeds (e.g., between four kilometers per hour (kph) and thirty kph) while delivering the particles to the trenches. Additionally, a particular spacing between the particles when disposed within the soil may enhance plant development and/or yield.

Accordingly, in certain embodiments, at least one row unit of the agricultural implement includes a particle delivery system configured to deliver the particles to the respective trench in the soil at a particular spacing while reducing the relative ground speed of the particles (e.g., the speed of the particles relative to the ground). The particle delivery system includes a particle disc configured to meter individual particles, thereby establishing the particular spacing between particles. The particle disc is configured to release each particle at a release point of the particle disc, thereby enabling the particle to move to a particle engagement section of a particle belt of the particle delivery system. The particle belt includes the particle engagement section, a particle acceleration section, and a particle exit section. The particle belt is configured to receive each particle at the particle engagement section, to accelerate each particle at the particle acceleration section, and to expel each particle toward the trench in the soil at the particle exit section.

In certain embodiments, the particle delivery system may include wheel(s) engaged with the particle belt and configured to rotate at different rotational speeds to stretch the particle belt at the particle acceleration section. For example, the wheels may be engaged with the particle belt, and a substantially no-slip condition may exist between each wheel and the particle belt. As used herein, a substantially no-slip condition refers to a condition in which a rotational speed of the wheel substantially matches a rotational speed of the portion of the particle belt in contact with the wheel, such that there is no slippage between the wheel and the particle belt as the wheel is engaged with and/or drives rotation of the particle belt. For example, the wheels may include protrusions (e.g., cogs) configured to interface with recesses of the particle belt to engage the particle belt and to establish the no slip condition.

In some embodiments, the particle delivery system may include hub assembly(ies) engaged with the particle belt and configured to stretch the particle belt at the particle acceleration section. For example, the hub assemblies may be engaged with the particle belt, and a substantially no-slip condition may exist between each hub assembly and the particle belt. Each hub assembly may include an outer hub configured to rotate, an inner hub disposed eccentrically within the outer hub and configured to rotate with the outer hub, cogs coupled to the inner hub and configured to pivot relative to the inner hub as the inner hub and the outer hub rotate, and guides coupled to the outer hub and configured to pivot relative to the outer hub. Each guide may be configured to slide along the respective cog and along the outer hub as the inner hub and the outer hub rotate, and each cog may be configured to engage the particle belt, such that the rotation of the inner hub and the outer hub and the pivoting of each cog stretches the particle belt.

In certain embodiments, the particle acceleration section of the particle belt may be stretched to accelerate the particle. For example, the particle belt may receive a particle at a particle engagement point disposed at the particle acceleration or before the particle acceleration section, and the particle may accelerate as the particle belt moves the particle along the particle acceleration section, such that a particle exit speed of each particle exiting the particle exit section of the particle belt reaches a target particle exit speed (e.g., after the particle passes through the particle acceleration section and is expelled from the particle belt at the particle exit section). The particle belt may accelerate each particle to a speed greater than a speed resulting from gravitational acceleration alone. As such, the particle delivery system may enable the row unit to travel faster than traditional row units that utilize seed tubes, which rely on gravity to accelerate the particles (e.g., seeds) for delivery to soil. Additionally, the particle belt may accelerate the particles such that the relative ground speed of the particles is reduced, thereby enabling the particle delivery system to accurately deposit the particles within the trench in soil.

With the foregoing in mind, the present embodiments relating to particle delivery systems may be utilized within any suitable agricultural implement. For example, FIG. **1** is a perspective view of an embodiment of an agricultural implement **10** having multiple row units **12** distributed across a width of the agricultural implement **10**. The implement **10** is configured to be towed through a field behind a work vehicle, such as a tractor. As illustrated, the implement **10** includes a tongue assembly **14**, which includes a hitch configured to couple the implement **10** to an appropriate tractor hitch (e.g., via a ball, clevis, or other coupling). The tongue assembly **14** is coupled to a tool bar **16** which supports multiple row units **12**. Each row unit **12** may include one or more opener discs configured to form a particle path (e.g., trench) within soil of a field. The row unit **12** may also include a particle delivery system (e.g., particle discs) configured to deposit particles (e.g., seeds, fertilizer, and/or other agricultural product(s)) into the particle path/trench. In addition, the row unit **12** may include closing disc(s) and/or a packer wheel positioned behind the particle delivery system. The closing disc(s) are configured to move displaced soil back into the particle path/trench, and the packer wheel is configured to pack soil on top of the deposited particles.

During operation, the agricultural implement **10** may travel at a particular speed along the soil surface while depositing the particles to the trenches. For example, a speed of the agricultural implement may be selected and/or controlled based on soil conditions, a type of the particles delivered by the agricultural implement **10** to the soil, weather conditions, a size/type of the agricultural implement, or a combination thereof. Additionally or alternatively, a particular spacing between the particles when disposed within the soil may enhance plant development and/or yield. Accordingly, in certain embodiments, at least one row unit **12** may include a particle delivery system configured to deposit the particles at the particular spacing while reducing the ground speed of the particles (e.g., as compared to a row unit that employs a particle tube to delivery particles to the soil). As discussed in detail below, the particle delivery system may include a particle metering and singulation unit configured to meter individual particles to establish the spacing between the particles. Additionally, the particle delivery system may include a particle belt configured to receive the particles from the particle metering and singulation unit and to accelerate the particles toward the trench in the soil. For example, a belt speed of the particle belt may be greater than a tangential speed of apertures of the particle disc. The particle belt may accelerate the particles to a speed greater than a speed resulting from gravitational acceleration alone and/or may reduce the relative ground speed of the particles (e.g., the speed of the particles relative to the ground). As such, the particle belt may enable the respective row unit **12** to travel faster than traditional row units that utilize seed tubes, while enabling the row unit **12** to accurately place each particle within the soil of the field.

FIG. **2** is a side view of an embodiment of a row unit **12** (e.g., agricultural row unit) that may be employed on the agricultural implement of FIG. **1**. The row unit **12** includes a mount **18** configured to secure the row unit **12** to the tool bar of the agricultural implement. In the illustrated embodiment, the mount **18** includes a U-bolt that secures a bracket **20** of the row unit **12** to the tool bar. However, in alternative embodiments, the mount may include another suitable device that couples the row unit to the tool bar. A linkage assembly **22** extends from the bracket **20** to a frame **24** of the row unit **12**. The linkage assembly **22** is configured to enable vertical movement of the frame **24** relative to the tool bar in response to variations in a soil surface **26**. In certain embodiments, a down pressure system (e.g., including a hydraulic actuator, a pneumatic actuator, etc.) may be coupled to the linkage assembly **22** and configured to urge the frame **24** toward the soil surface **26**. While the illustrated linkage assembly **22** is a parallel linkage assembly (e.g., a four-bar linkage assembly), in alternative embodiments, another suitable linkage assembly may extend between the bracket and the frame.

The row unit **12** includes an opener assembly **30** that forms a trench **31** in the soil surface **26** for particle deposition into the soil. In the illustrated embodiment, the opener assembly **30** includes gauge wheels **32**, arms **34** that pivotally couple the gauge wheels **32** to the frame **24**, and opener discs **36**. The opener discs **36** are configured to excavate the trench **31** into the soil, and the gauge wheels **32** are configured to control a penetration depth of the opener discs **36** into the soil. In the illustrated embodiment, the row unit **12** includes a depth control system **38** configured to control the vertical position of the gauge wheels **32** (e.g., by blocking rotation of the arms in the upward direction beyond a selected orientation), thereby controlling the penetration depth of the opener discs **36** into the soil.

The row unit **12** includes a particle delivery system **40** configured to deposit particles (e.g., seeds, fertilizer, and/or other agricultural product(s)) into the trench **31** as the row unit **12** traverses the field along a direction of travel **42**. As illustrated, the particle delivery system **40** includes a particle metering and singulation unit **44** configured to receive the particles (e.g., seeds) from a hopper assembly **46** (e.g., a particle storage area). In certain embodiments, a hopper of the hopper assembly may be integrally formed with a housing of the particle metering and singulation unit. The hopper assembly **46** is configured to store the particles for subsequent metering by the particle metering and singulation unit **44**. As will be described in greater detail below, in some embodiments, the particle metering and singulation unit **44** includes a particle disc configured to rotate to transfer the particles from the hopper assembly **46** toward a particle belt of the particle delivery system **40**. The particle belt may generally be disposed between the particle metering and singulation unit **44** and the trench **31**.

The opener assembly **30** and the particle delivery system **40** are followed by a closing assembly **48** that moves displaced soil back into the trench **31**. In the illustrated embodiment, the closing assembly **48** includes two closing discs **50**. However, in alternative embodiments, the closing assembly may include other closing devices (e.g., a single closing disc, etc.). In addition, in certain embodiments, the closing assembly may be omitted. In the illustrated embodiment, the closing assembly **48** is followed by a packing assembly **52** configured to pack soil on top of the deposited particles. The packing assembly **52** includes a packer wheel **54**, an arm **56** that pivotally couples the packer wheel **54** to the frame **24**, and a biasing member **58** configured to urge the packer wheel **54** toward the soil surface **26**, thereby causing the packer wheel to pack soil on top of the deposited particles (e.g., seeds and/or other agricultural product(s)). While the illustrated biasing member **58** includes a spring, in alternative embodiments, the biasing member may include another suitable biasing device, such as a hydraulic cylinder or a pneumatic cylinder, among others. For purposes of discussion, reference may be made to a longitudinal axis or direction **60**, a vertical axis or direction **62**, and a lateral axis or direction **64**. For example, the direction of travel **42** of the row unit **12** may be generally along the longitudinal axis **60**.

FIG. **3** is a side view of an embodiment of a particle delivery system **40** that may be employed within the row unit of FIG. **2**. As described above, the particle delivery system **40** is configured to meter and accelerate particles **80** (e.g., seeds, fertilizer, other particulate material, or a combination thereof) toward the trench **31** for deposition into the trench **31**. In the illustrated embodiment, the particle delivery system **40** includes a particle disc **82** (e.g., of the particle metering and singulation unit **44**) configured to meter the particles **80** and a particle belt **84** (e.g., an endless member) configured to accelerate and move the particles **80** toward the trench **31** for deposition into the trench **31**.

The particle disc **82** has apertures **90** configured to receive the particles **80** from a particle hopper **92** of the particle delivery system **40**. For example, each aperture **90** may receive a single particle **80**. The particle hopper **92** is a particle storage area configured to store the particles **80** for subsequent metering and distribution. In certain embodiments, the particle hopper **92** may be coupled to and/or included as part of a housing of the particle metering and singulation unit **44**. Furthermore, in some embodiments, the hopper assembly may provide the particles **80** to the particle hopper **92**, and/or the hopper assembly (e.g., the hopper of the hopper assembly) may be coupled to the particle hopper **92**. The particle disc **82** is configured to rotate, as indicated by arrow **94**, to move the particles **80** from the particle hopper **92** to a release point **96**, where the particles **80** are released such that the particles **80** move downwardly toward the particle belt **84**. The particle belt **84** is configured to rotate, as indicated by arrows **98**, to move and expel the particles **80** toward the trench **31**. The particle disc **82** having the apertures **90** may be any suitable shape configured to rotate/move to transfer the particles **80** from the particle hopper **92** to the release point **96**. For example, the particle disc **82** may be generally flat, may have a curved portion and a flat portion, may be entirely curved, may be a drum, or may include other suitable shapes, geometries, and/or configurations. In certain embodiments, an inner portion of the particle disc **82** may curved/raised related to an outer portion of the particle disc **82** having the apertures **90** (e.g., the particle disc **82** may be generally bowl-shaped), such that the particles **80** may be directed toward the apertures **90** (e.g., away from the raised inner portion and/or toward the flat outer portion) as the particle disc **82** rotates. In some embodiments, the particle disc **82** may be a drum having the apertures **90** disposed along an outer portion and/or an exterior of the drum.

As illustrated, the particle delivery system **40** includes an air flow system **100** having an air flow device **102** (e.g., a vacuum source), a first air tube **104** fluidly coupled to the air flow device **102**, and a second air tube **106** fluidly coupled to the air flow device **102**. The air flow system **100** is configured to reduce the air pressure within a vacuum passage **110** positioned along a portion of the particle disc **82**, thereby drawing the particles **80** from the particle hopper **92** toward and against the apertures **90**. As illustrated, the first air tube **104** is fluidly coupled to the air flow device **102** and to the vacuum passage **110**. The air flow device **102** is configured to draw air through the apertures **90** aligned with the vacuum passage **110**, via the first air tube **104**. As the particle disc **82** rotates, the vacuum formed at the apertures **90** secures the particles **80** to the particle disc **82** at the apertures **90**, such that the particle disc **82** moves each particle **80** from the particle hopper **92** to the release point **96**. At the release point **96**, the air flow system **100** provides, via the second air tube **106**, an air flow **112** configured to remove each particle **80** from the respective aperture **90** (e.g., by overcoming the vacuum formed at the respective aperture **90**). In certain embodiments, the air flow **112** may be omitted, and the particles **80** may be released from the apertures **90** due to the vacuum passage **110** ending. For example, at the release point **96**, the vacuum passage **110** may end (e.g., the air flow device **102** may no longer draw air through the apertures **90** of the particle disc **82** at the release point **96**), and the particles **80** may no longer be secured in the apertures **90**. The particles **80** are released from the particle disc **82** along a release trajectory **114**. Rotation of the particle disc **82** imparts a velocity on the particles, and the particles **80** accelerate from the particle disc **82** along the release trajectory **114** under the influence of gravity and/or due to the force applied by the air flow **112**. In some embodiments, an angle between the release trajectory **114** and the vertical axis **62** may be zero degrees, one degree, two degrees, five degrees, ten degrees, twenty degrees, or other suitable angles. As used herein, "vacuum" refers to an air pressure that is less than the ambient atmospheric air pressure, and not necessarily 0 pa.

The particle delivery system **40** includes a disc housing **120** and a particle belt housing **122**. The particle disc **82** is disposed within and configured to rotate within the disc housing **120**. The particle belt **84** is disposed within and configured to rotate within the particle belt housing **122**. The vacuum passage **110** of the particle metering and singulation unit **44** is formed within the disc housing **120**. Additionally, the particle metering and singulation unit **44** includes the particle disc **82** and the disc housing **120**. The particle hopper **92** (e.g., the particle storage area) is formed within the disc housing **120**.

Additionally, the particle delivery system **40** includes a particle tube **124** coupled to the disc housing **120** and the particle belt housing **122**. The particle tube **124** extends generally from the release point **96** to a particle engagement section **130** of the particle belt **84** and is configured to at least partially direct the particles **80** from the particle disc **82** (e.g., from the release point **96** of the particle disc **82**) to the particle belt **84** (e.g., to the particle engagement section **130** of the particle belt **84**) along the release trajectory **114**. The particle tube may include any suitable shape and/or configuration configured to at least particle direct the particles, such as a channel, a cylindrical tube, a rectangular tube, and/or other suitable shapes/configurations. In certain embodiments, the particle tube may be omitted, such that the particles flow from the release point to the engagement point without guidance from the particle tube.

The particle belt **84** includes the particle engagement section **130**, a particle acceleration section **132**, a particle exit section **134**, and a belt retraction section **136**. The particle belt **84** is configured to receive the particles **80** from the particle metering and singulation unit **44** at the particle engagement section **130**, to accelerate the particles **80** at and/or along the particle acceleration section **132**, and to expel the particles **80** toward the trench **31** along a release trajectory **137** at the particle exit section **134**. For example, the particle belt **84** is configured to rotate, as indicated by arrows **138**, to move the particles **80** from the particle engagement section **130** to the particle exit section **134**. As described in greater detail below, the particle belt **84** is configured to stretch at the particle acceleration section **132** and to retract at the belt retraction section **136**. The particle belt **84** includes a base **140** and flights **142** coupled to and extending from the base **140**. Each pair of opposing flights **142** is configured to receive a respective particle **80** at the particle engagement section **130** and to move the respective particle **80** to the particle exit section **134**.

As described above, the particle disc **82** is configured to meter the particles **80** and to provide a spacing between the particles **80**. The spacing between the particles **80** when disposed within the trench **31** may enhance plant development and/or yield. Additionally, the particle delivery system **40** is configured to accelerate the particles **80** generally toward and along the trench **31**. The acceleration of the particles **80** by the particle delivery system **40** along the trench may reduce a relative ground speed of the particles **80**, as compared to particles output by a seed tube, which relies solely on gravity to accelerate the particles for delivery to soil. For example, the particle delivery system **40** is configured to accelerate the particles **80** using the air flow system **100**, gravity, and the particle belt **84**. The air flow system **100** is configured to provide the air flow **112** from the second air tube **106** to accelerate the particles **80** along the release trajectory **114** (e.g., the air flow system **100** may apply a force to the particles **80** via the air flow **112**). Additionally, the particle delivery system **40** is configured to enable the particles **80** to accelerate under the influence of gravity as the particles **80** travel between the particle disc **82** and the particle belt **84**. The particle belt **84** is configured to accelerate the particles **80** received from the particle disc **82**, such that a particle exit speed of each particle **80** expelled from the particle belt **84** along the release trajectory **137** reaches a target particle exit speed. The particle exit speed of each particle **80** may reach the target particle exit speed when the particle exit speed is equal to the target particle exit speed, when the particle exit speed becomes greater than or less than the target particle exit speed, when the particle exit speed is within a threshold range of the target particle exit speed (e.g., a difference between the particle exit speed and the target particle exit speed is less than a threshold value associated with the threshold range), or a combination thereof.

The particle delivery system **40** is configured to accelerate the particles **80** at the particle acceleration section **132** of the particle belt **84**. Specifically, the particle delivery system **40** includes a first wheel **150** engaged with the particle belt **84** at a first location **152** (e.g., an interface between the first wheel **150** and the particle belt **84**) and a second wheel **154** engaged with the particle belt **84** at a second location **156** (e.g., an interface between the second wheel **154** and the particle belt **84**). The second wheel **154** is configured to rotate faster than the first wheel **150** to stretch the particle belt **84** at the particle acceleration section **132**, thereby accelerating the particles **80** moving along the particle acceleration section **132** and expelled from the particle exit section **134**. To enable stretching the particle belt **84** at the particle acceleration section **132**, a substantially no-slip condition exists between the first wheel **150** and the particle belt **84** at the first location **152** and between the second wheel **154** and the particle belt **84** at the second location **156**. After stretching at the particle acceleration section **132**, the particle belt **84** is configured to retract (e.g., at least partially relax) at the belt retraction section **136**. The particle belt **84** (e.g., the base **140** and/or the flights **142** of the particle belt **84**) may be formed from an elastic material (e.g., fabric, rubber, plastic, or a combination thereof) configured to stretch and/or retract.

As illustrated, the particle engagement section **130** of the particle belt **84** is positioned generally at the first location **152**. In certain embodiments, the particle engagement section may be positioned between the first location and the second location, such that the particle belt receives the particles at a stretched portion of the particle belt (e.g., a spacing between flights of the particle belt may be the same at the particle engagement section and the particle acceleration section) or adjacent to the particle retraction section. Additionally, as illustrated, the particle exit section **134** of the particle belt **84** is positioned generally at the second location **156**. In certain embodiments, the particle exit section may be positioned between the first location and the second location.

The first wheel **150** and the second wheel **154** are configured to rotate to drive rotation of the particle belt **84**. In certain embodiments, only one of the first wheel and the second wheel may be configured to drive rotation of the particle belt. As described in greater detail in reference to FIGS. **4** and **5**, the first wheel **150** and the second wheel **154** may be coupled to one another, via a drive mechanism, such that rotation of the first wheel **150** drives rotation of the second wheel **154**, and a first rotational speed of the first wheel **150** is proportional to a second rotational speed of the second wheel **154**. The first wheel **150** and/or the second wheel **154** may include pulley(s) and/or gear(s).

The first wheel **150** includes an outer peripheral portion **157** (e.g., a first wheel portion) and protrusions **158** (e.g., first protrusions, cogs) extending from the outer peripheral portion **157**. Additionally, the second wheel includes an outer peripheral portion **159** (e.g., a second wheel portion) and protrusions **160** (e.g., second protrusions, cogs) extending from the outer peripheral portion **159**. Each of the protrusions **158** and **160** is configured to engage a respective recess of the particle belt **84** to provide the no-slip condition between the first wheel **150** and the particle belt **84** at the first location **152** and between the second wheel **154** and the particle belt **84** at the second location **156**, respectively.

The number of protrusions **158** and **160** may generally depend on the first expected rotational speed of the first wheel **150**, the second expected rotational speed of the second wheel **154**, a diameter **161** (e.g., a first diameter) of the first wheel **150**, a diameter **162** (e.g., a second diameter) of the second wheel **154**, or a combination thereof. For example, the number of protrusions, the rotational speed, and the diameter of the first wheel **150** and the second wheel **154** may each be proportionally related (e.g., as the expected rotational speed of the wheel increases or decreases, the number of protrusions and/or the diameter of the wheel may increase or decrease). As illustrated, the first wheel **150** includes eight protrusions **158**, and the second wheel **154** includes four protrusions **160**. Additionally, the diameter **161** of the first wheel **150** and the diameter **162** of the second wheel **154** are generally the same. As such, the second wheel **154** rotating faster than (e.g., twice as fast as) the first wheel **150** may stretch the particle belt **84** at the particle acceleration section **132**, such that the belt speed of the particle belt **84** at the second location **156** (e.g., at the particle exit section **134**) is twice a belt speed of the particle belt **84** at the particle engagement section **130** and/or at the belt retraction section **136**. In other embodiments, the number of protrusions, the rotational speed, and the diameter of the first wheel and/or the second wheel may have other values that may increase and/or decrease the belt speed of the particle belt at the particle exit section, thereby increasing and/or decreasing the particle exit speed of the particles. As described in greater detail below, the number of protrusions **158** of the first wheel **150** and the number of protrusions **160** of the second wheel **154** may be selected based on relative diameters of the first wheel **150** and the second wheel **154** (e.g., diameters of first ends of the first wheel **150** and the second wheel **154**, which are engaged with the particle belt **84**, and diameters of second ends of the first wheel **150** and the second wheel **154**, which are engaged with a drive mechanism).

The particle delivery system **40** includes a belt tension assembly **164** configured to at least partially maintain a tension of the particle belt **84** at the belt retraction section **136**. For example, at the belt retraction section **136**, the particle belt **84** may be more retracted (e.g., more relaxed) relative to the particle acceleration section **132** and/or the particle exit section **134**, and the belt tension assembly **164** may provide a force/pressure to the particle belt **84** at the belt retraction section **136** to remove slack from the particle belt **84** and at least partially maintain the tension of the particle belt **84**. As illustrated, the belt tension assembly **164** includes a track **165** and a wheel **166** (e.g., a third wheel) coupled to and configured to move along the track **165**. The wheel **166** is engaged with the particle belt **84** at the belt retraction section **136** to provide the tension to the belt retraction section **136** of the particle belt **84**. For example, the wheel **166** may be biased outwardly toward the particle belt **84**, as indicated by arrow **167**, to at least partially maintain the tension of the particle belt **84** at the belt retraction section **136**. In certain embodiments, the belt tension assembly **164** may include a spring and/or another tension mechanism configured to bias the wheel **166** outwardly along the track **165**. In some embodiments, the belt tension assembly, or portions thereof, may be omitted from the particle delivery system. For example, the belt retraction section may remain in tension due to the no-slip conditions between the first wheel and the particle belt at the first location and between the second wheel and the particle belt at the second location. Alternatively, the belt retraction section may not be in tension and may have slack, and/or the belt retraction section may alternate between having slack and being in tension.

The particle delivery system **40** includes a controller **170** configured to control the rotation rate (e.g., the rotational speed) of the particle disc **82** to adjust/control the spacing between the particles **80**. For example, the controller **170** may control a first motor **172**, which is configured to drive rotation of the particle disc **82**, to adjust/control the rotation rate of the particle disc **82** (e.g., by outputting an output signal to the first motor **172** indicative of instructions to adjust the rotation rate of the particle disc **82**). Additionally, the controller **170** may control the first motor **172** to achieve a target spacing between the particles **80**. The controller **170** may determine the target spacing between the particles **80** based on a type of the particles **80**, an input received from a user interface, a ground speed of the row unit, or a combination thereof. The spacing may be any suitable spacing, such as one centimeter, two centimeters, five centimeters, ten centimeters, fifty centimeters, one meter, two meters, five meters, etc. In certain embodiments, the controller **170** may control the rotation rate of the particle disc **82** (e.g., via control of the first motor **172**) to achieve the target spacing based on a reference table identifying rotational speeds of the particle disc **82** that will achieve particular spacings, based on an empirical formula, in response to sensor feedback, or a combination thereof.

In certain embodiments, the controller **170** is configured to control the air flow **112** provided by the air flow system **100** to adjust/control a particle transfer speed of each particle **80** expelled from the particle disc **82** (e.g., from the release point **96** of the particle disc **82**, along the release trajectory **114**, and toward the particle engagement section **130** of the particle belt **84**), such that the particle transfer speed reaches a target particle transfer speed at the particle engagement section **130**. For example, the controller **170** may control the air flow device **102**, which is configured to provide the air flow **112** to accelerate each particle **80** along the release trajectory **114**. In certain embodiments, the controller **170** may control a valve configured to adjust a flow rate of the air flow **112**. The controller **170** may determine the target particle transfer speed of the particles **80** based on the belt speed of the particle belt **84** and/or the type of the particles **80**. The target particle transfer speed may be any suitable speed, such one-tenth kph, one-half kph, one kph, two kph, three kph, five kph, ten kph, fifteen kph, twenty kph, etc. In certain embodiments, the controller **170** may determine the target particle transfer speed as a target percentage of the belt speed of the particle belt **84** (e.g., thirty percent, fifty percent, seventy percent, eighty percent, ninety percent, ninety-five percent, etc.).

To control the air flow **112** provided by the air flow system **100**, the controller **170** may receive an input signal indicative of the particle transfer speed of the particle **80** at the particle engagement section **130** of the particle belt **84**. For example, the controller **170** may receive the input signal from a particle sensor **174** of the particle delivery system **40** disposed within the particle tube **124**. The particle sensor **174** may include an infrared sensor or another suitable type of sensor configured to output the input signal indicative of the particle transfer speed of each particle **80** at the particle engagement section **130**. The particle sensor **174** may be positioned a fixed distance from the particle engagement section **130**, such that the controller **170** may determine the particle transfer speed of the particle **80** at the particle engagement section **130** based on the fixed distance and the input signal indicative of the particle transfer speed received from the particle sensor **174** (e.g., based on gravitational acceleration of the particle **80** traveling the fixed distance from the particle sensor **174** to the particle engagement section **130** and/or based on acceleration due to the air flow **112**).

The controller **170** may compare the particle transfer speed of the particle **80** at the particle engagement section **130** to the target particle transfer speed to determine whether a difference between the particle transfer speed and the target particle transfer speed exceeds a threshold value. In response to determining that the particle transfer speed at the particle engagement section **130** is less than the target particle transfer speed and the difference between the particle transfer speed and the target particle transfer speed exceeds the threshold value, the controller **170** may output an output signal indicative of instructions to increase the flow rate of the air flow **112** provided by the air flow system **100** through the second air tube **106**. For example, the controller **170** may output the output signal to the air flow device **102** to cause the air flow device **102** to increase the flow rate of the air flow **112**. The increase in the air flow rate may increase the particle transfer speed, such that the particle transfer speed reaches the target particle transfer speed (e.g., such that the difference between the particle transfer speed and the target particle transfer speed is less than the threshold value).

In response to determining that the particle transfer speed at the particle engagement section **130** is greater than the target particle transfer speed and the difference between the particle transfer speed and the target particle transfer speed exceeds the threshold value, the controller **170** may output an output signal indicative of instructions to decrease the flow rate of the air flow **112** provided by the air flow system **100**. For example, the controller **170** may output the output signal to the air flow device **102** to cause the air flow device **102** to decrease the flow rate of the air flow **112**. The decrease in the air flow rate may decrease the particle transfer speed, such that the particle transfer speed reaches the target particle transfer speed (e.g., such that the difference between the particle transfer speed and the target particle transfer speed is less than the threshold value).

Additionally, the controller **170** is configured to control the belt speed of the particle belt **84** to adjust/control the particle exit speed of the particles **80** expelled from the particle belt **84** (e.g., from the particle exit section **134** of the particle belt **84**, along the release trajectory **137**, and toward the trench **31**), such that the particle exit speed reaches a target particle exit speed. For example, the controller **170** may control the first wheel **150**, via a second motor **176** configured to drive rotation of the first wheel **150** and the particle belt **84**, to adjust/control the belt speed of the particle belt **84** (e.g., by outputting an output signal to the second motor **176** indicative of instructions to adjust the rotation rate of the first wheel **150**), thereby adjusting/controlling the particle exit speed of the particles **80**. The controller **170** may control the particle exit speed of the particles **80**, such that the particle exit speed reaches the target particle exit speed. The controller **170** may determine the target particle exit speed of the particles **80** based on the type of the particles **80**, the size of the particles **80**, an input received from a user interface, the ground speed of the row unit, or a combination thereof. The target particle exit speed may be any suitable speed, such one kilometer per hour (kph), two kph, three kph, five kph, ten kph, fifteen kph, twenty kph, etc. In certain embodiments, the controller **170** may determine the target particle exit speed as a target percentage of the ground speed of the row unit (e.g., thirty percent, fifty percent, sixty percent, seventy percent, eighty percent, ninety percent, ninety-five percent, one hundred percent, etc.).

To control the belt speed of the particle belt **84**, the controller **170** may receive an input signal indicative of the particle exit speed of the particle **80** at the particle exit section **134** of the particle belt **84**. For example, the controller **170** may receive the input signal from a particle sensor **178** of the particle delivery system **40** disposed adjacent to the particle exit section **134** and along the release trajectory **137**. The particle sensor **178** may include an infrared sensor or another suitable type of sensor configured to output the input signal indicative of the particle exit speed of each particle **80** at the particle exit section **134**. The particle sensor **178** may be positioned a fixed distance from the particle exit section **134** of the particle belt **84**, such that the controller **170** may determine the particle exit speed of the particle **80** at the particle exit section **134** based on the fixed distance and the input signal indicative of the particle exit speed received from the particle sensor **178** (e.g., based on acceleration and/or deceleration of the particle **80** traveling the fixed distance). In certain embodiments, the particle sensor **178** may be configured output a signal indicative of the ground speed of the agricultural row unit to the controller **170**, and/or the controller **170** may receive the signal indicative of the ground speed from another source. In some embodiments, the particle sensor **174** and/or the particle sensor **178** may be omitted from the particle delivery system **40**. In certain embodiments, the controller **170** may determine other information related to the particles **80** based on feedback from the particle sensor **178**, such as skips (e.g., the particle **80** not being present during an expected time period), multiple particles **80** (e.g., multiple particles **80** being present when only a single particle **80** is expected), an amount of particles **80** deposited over a given area (e.g., an amount of particles **80** deposited per acre), and other information related to the particles **80**. In some embodiments, the controller **170** may control the particle delivery system based on such feedback.

The controller **170** may compare the particle exit speed of the particle **80** at the particle exit section **134** of the particle belt **84** to the target particle exit speed to determine whether a difference between the particle exit speed and the target particle exit speed exceeds a threshold value. In response to determining that the particle exit speed at the particle exit section **134** of the particle belt **84** is less than the target particle exit speed and the difference between the particle exit speed and the target particle exit speed exceeds the threshold value, the controller **170** may output an output signal indicative of instructions to increase the belt speed of the particle belt **84**. For example, the controller **170** may output the output signal to the second motor **176** to cause the second motor **176** to increase the rotation rate of the first wheel **150**, thereby increasing the belt speed of the particle belt **84**. The increase in the belt speed of the particle belt **84** may increase the particle exit speed, such that the particle exit speed reaches the target particle exit speed (e.g., such that the difference between the particle exit speed and the target particle exit speed is less than the threshold value).

In response to determining that the particle exit speed at the particle exit section **134** of the particle belt **84** is greater than the target particle exit speed and the difference between the particle exit speed and the target particle exit speed exceeds the threshold value, the controller **170** may output an output signal indicative of instructions to decrease the belt speed of the particle belt **84**. For example, the controller **170** may output the output signal to the second motor **176** to cause the second motor **176** to decrease the rotation rate of the first wheel **150**, thereby decreasing the belt speed of the particle belt **84**. The decrease in the belt speed of the particle belt **84** may decrease the particle exit speed, such that the particle exit speed reaches the target particle exit speed (e.g., such that the difference between the particle exit speed and the target particle exit speed is less than the threshold value).

As illustrated, the controller **170** of the particle delivery system **40** includes a processor **190** and a memory **192**. The processor **190** (e.g., a microprocessor) may be used to execute software, such as software stored in the memory **192** for controlling the particle delivery system **40** (e.g., for controlling a rotational speed of the particle disc **82**, the belt speed of the particle belt **84**, and the air flow **112** provided by the air flow system **100**). Moreover, the processor **190** may include multiple microprocessors, one or more "general-purpose" microprocessors, one or more special-purpose microprocessors, and/or one or more application specific integrated circuits (ASICS), or some combination thereof. For example, the processor **190** may include one or more reduced instruction set (RISC) or complex instruction set (CISC) processors.

The memory device **192** may include a volatile memory, such as random access memory (RAM), and/or a nonvolatile memory, such as read-only memory (ROM). The memory device **192** may store a variety of information and may be used for various purposes. For example, the memory device **192** may store processor-executable instructions (e.g., firmware or software) for the processor **190** to execute, such as instructions for controlling the particle delivery system **40**. In certain embodiments, the controller **170** may also include one or more storage devices and/or other suitable components. The storage device(s) (e.g., nonvolatile storage) may include ROM, flash memory, a hard drive, or any other suitable optical, magnetic, or solid-state storage medium, or a combination thereof. The storage device(s) may store data (e.g., the target particle transfer speed and/or the target particle exit speed), instructions (e.g., software or firmware for controlling the particle delivery system **40**), and any other suitable data. The processor **190** and/or the memory device **192**, and/or an additional processor and/or memory device, may be located in any suitable portion of the system. For example, a memory device for storing instructions (e.g., software or firmware for controlling portions of the particle delivery system **40**) may be located in or associated with the particle delivery system **40**.

Additionally, the particle delivery system **40** includes a user interface **194** is communicatively coupled to the controller **170**. The user interface **194** may be configured to inform an operator of the particle transfer speed and/or the particle exit speed of the particles **80**, to enable the operator to adjust the rotational speed of the particle disc **82** and/or the spacing between the particles **80**, to enable the operator to adjust the belt speed of the particle belt **84** and/or the air flow **112** provided by the air flow system **100**, to provide the operator with selectable options of the type of particles **80**, and to enable other operator interactions. For example, the user interface **194** may include a display and/or other user interaction devices (e.g., buttons) configured to enable operator interactions.

FIG. **4** is a side view of an embodiment of the particle belt **84** and the first wheel **150** of the particle delivery system of FIG. **3**. As described above, a substantially no-slip condition exists between the particle belt **84** and the first wheel **150** at the first location **152**. Additionally, the substantially no-slip condition exists between the second wheel and the particle belt at the second location. The substantially no-slip conditions enable the first wheel **150** and the second wheel rotating at different speeds to stretch the particle belt **84** at the particle acceleration section **132**, thereby accelerating the particles **80** at the particle acceleration section **132**.

As illustrated, the particle belt **84** has recesses **200** formed along the base **140** and configured to receive the protrusions **158** of the first wheel **150**. The interface between the protrusions **158** and the recesses **200** (e.g., the protrusions **158** extending into the recesses **200**) provides the no-slip condition at the first location **152**. For example, as the first wheel **150** rotates, as indicated by arrow **202**, the protrusions **158** may rotate/move at the same speed as the particle belt **84** at the first location **152**. As illustrated, the protrusions **158** and the recesses **200** are semi-circles configured to engage one another. In other embodiments, the protrusions and the recesses may be other suitable shapes configured to engage one another (e.g., squares, rectangles, etc.). In certain embodiments, the first wheel and/or the particle belt may include other mechanisms configured to provide the substantially no-slip condition, such as rough surfaces. The protrusions of the second wheel may be shaped similarly to the protrusions **158** of the first wheel **150**, such that the protrusions of the second wheel engage the recesses **200** of the particle belt **84** and provide the no-slip condition between the second wheel and the particle belt **84** at the second location.

FIG. **5** is a rear view of the particle belt **84**, the first wheel **150** engaged with the particle belt **84**, the second wheel **154** engaged with the particle belt **84**, and a drive mechanism **220** of the particle delivery system. The first wheel **150** includes a first end **222** engaged with the particle belt **84** at the first location **152** and a second end **224** disposed generally opposite the first end **222** and engaged with the drive mechanism **220** at a third location **226**. Additionally, the second wheel **154** includes a first end **230** (e.g., a third end) engaged with the particle belt **84** at the second location **156** and a second end **232** (e.g., a fourth end) disposed generally opposite the first end **230** and engaged with the drive mechanism **220** at a fourth location **234**.

As described above, the second motor **176** is configured to drive rotation of the first wheel **150**. Rotation of the first wheel **150** is configured to drive rotation of the drive mechanism **220**, which is configured to drive rotation of the second wheel **154**. As illustrated, the drive mechanism **220** is a chain configured to engage protrusions **236** of the first wheel **150** at the second end **224** of the first wheel **150** and to engage protrusions **238** of the second wheel **154** at the second end **232** of the second wheel **154**.

The second end **224** of the first wheel **150** has a diameter **240** that is generally equal to the diameter **161** of the first end **222** of the first wheel **150** and generally equal to the diameter **162** of the first end **230** of the second wheel **154**. The second end **232** of the second wheel **154** has a diameter **242** that is smaller than the diameter **240** of the second end **224** of the first wheel **150**, such that rotation of the drive mechanism **220** by the second end **224** of the first wheel **150** at a first rotational speed drives rotation of the second end **232** of the second wheel **154** at a second rotational speed faster than the first rotational speed. The faster second rotational speed of the second wheel **154** (e.g., at the first end **230** and at the second end **232** of the second wheel **154**) relative to the first rotational speed of the first wheel **150** (e.g., at the first end **222** and at the second end **224** of the first wheel **150**) causes the second wheel **154** to stretch the particle belt **84** at the particle acceleration section **132**, thereby accelerating the particles.

As illustrated, the diameter **240** of the second end **224** of the first wheel **150** is about twice as large as the diameter **242** of the second end **232** of the second wheel **154**, such that rotation of the drive mechanism **220** drives rotation of the second wheel **154** at the second rotational speed that is about twice as fast as the first rotational speed of the first wheel **150**. In certain embodiments, the diameter of the second end of the first wheel may be larger or smaller relative to the diameter of the second end of the second wheel (e.g., compared to the illustrated embodiment), such that a proportional relationship of the second rotational speed of the second wheel relative to the first rotational speed of the first wheel is different (e.g., the second wheel may rotate three times as fast as the first wheel, the second wheel may rotate four times as fast as the first wheel, the second wheel may rotate eight times as a fast as the first wheel, etc.). The drive mechanism **220** is not stretchable, such that the proportional relationship between the first rotational speed of the first wheel **150** and the second rotational speed of the second wheel **154** is maintained.

FIG. **6** is a rear view of an embodiment of the particle belt **84**, a first wheel **260** engaged with the particle belt **84**, a second wheel **262** engaged with the particle belt **84**, and a drive mechanism **264** of a particle delivery system that may be employed within the row unit of FIG. **2**. The first wheel **260** includes a first end **266** engaged with the particle belt **84** at a first location **268** and a second end **270** disposed generally opposite the first end **266** and engaged with the drive mechanism **264** at a third location **272**. Additionally, the second wheel **262** includes a first end **274** (e.g., a third end) engaged with the particle belt **84** at a second location **276** and a second end **278** (e.g., a fourth end) disposed generally opposite the first end **274** and engaged with the drive mechanism **264** at a fourth location **280**.

The second motor **176** is configured to drive rotation of the first wheel **260**. Rotation of the first wheel **260** is configured to drive rotation of the drive mechanism **264**, which is configured to drive rotation of the second wheel **262**. As illustrated, the drive mechanism **264** includes a drive shaft having a first end **284** and a second end **286** that are beveled (e.g., the drive mechanism **264** may be a beveled gear). The second end **270** of the first wheel **260** is beveled and is engaged with the first end **284** of the drive mechanism **264** (e.g., grooves **287** of the second end **270** of the first wheel **260** are engaged with grooves **288** of the first end **284** of the drive mechanism **264**).

Additionally, the second end **278** of the second wheel **262** is beveled and is engaged with the second end **286** of the drive mechanism **264** (e.g., grooves **289** of the second end **278** of the second wheel **262** are engaged with grooves **290** of the second end **286** of the drive mechanism **264**).

The second end **270** of the first wheel **260** has a diameter **291** that is generally equal to a diameter **292** of the first end **266** of the first wheel **260** and generally equal to a diameter **294** of the first end **274** of the second wheel **262**. The second end **278** of the second wheel **262** has a diameter **296** that is smaller than the diameter **291** of the second end **270** of the first wheel **260**, such that rotation of the drive mechanism **264** by the second end **270** of the first wheel **260** at a first rotational speed drives rotation of the second end **278** of the second wheel **262** at a second rotational speed faster than the first rotational speed. The faster second rotational speed of the second wheel **262** (e.g., at the first end **274** and at the second end **278** of the second wheel **262**) relative to the first rotational speed of the first wheel **260** (e.g., at the first end **266** and at the second end **270** of the first wheel **260**) causes the second wheel **262** to stretch the particle belt **84** at the particle acceleration section **132**, thereby accelerating the particles.

As illustrated, the diameter **291** of the second end **270** of the first wheel **260** is about twice as large as the diameter **296** of the second end **278** of the second wheel **262**, such that rotation of the drive mechanism **264** drives rotation of the second wheel **262** at the second rotational speed that is about twice as fast as the first rotational speed of the first wheel **260**. In certain embodiments, the diameter of the second end of the first wheel may be larger or smaller relative to the diameter of the second end of the second wheel (e.g., compared to the illustrated embodiment), such that a proportional relationship of the second rotational speed of the second wheel relative to the first rotational speed of the first wheel is different (e.g., the second wheel may rotate three times as fast as the first wheel, the second wheel may rotate four times as fast as the first wheel, the second wheel may rotate eight times as a fast as the first wheel, etc.).

In certain embodiments, the particle delivery system may include a third motor coupled to and configured to drive rotation of the second wheel independent of the first wheel. For example, the controller may be communicatively coupled to the third motor, such that the controller may control rotation of the second wheel independent of the first wheel. In such embodiments, the drive mechanism coupling the first wheel and the second wheel may be omitted.

FIG. **7** is a side view of another embodiment of a particle delivery system **300** that may be employed within the row unit of FIG. **2**. As illustrated, the particle delivery system **300** includes the particle metering and singulation unit **44**, which includes the particle disc **82**, configured to meter and establish the spacing between the particles **80**. The particle delivery system **300** also includes a particle belt **302** (e.g., an endless member) configured to receive the particles **80** from the particle disc **82** and to expel the particles **80** into the trench **31**. Additionally, the particle delivery system **300** includes the air flow system **100** configured to provide the vacuum along the vacuum passage **110** adjacent to the particle disc **82** and/or to remove the particles **80** from the particle disc **82** and accelerate the particles **80** along the release trajectory **114** via the air flow **112**.

The particle delivery system **300** includes a particle belt housing **304**. The particle belt **302** is disposed within and configured to rotate within the particle belt housing **304**. Additionally, the particle delivery system **40** includes the particle tube **124** coupled to the disc housing **120** and the particle belt housing **304**. The particle tube **124** extends generally from the release point **96** to a particle engagement point **310** of the particle belt **302** and is configured to at least partially direct the particles **80** from the particle disc **82** (e.g., from the release point **96** of the particle disc **82**) to the particle belt **302** (e.g., to the particle engagement point **310** of the particle belt **302**) along the release trajectory **114**. In certain embodiments, the particle tube may be omitted, such that the particles flow from the release point to the engagement point without guidance from the particle tube.

The particle belt **302** includes a particle acceleration section **312**, a particle transfer section **313**, a particle exit section **314**, and a belt retraction section **316**. The particle belt **302** is configured to receive the particles **80** from the particle metering and singulation unit **44** at the particle engagement point **310**, to accelerate the particles **80** at and/or along the particle acceleration section **312**, to transfer the particles **80** from the particle acceleration section **312** to the particle exit section **314** at and/or along the particle transfer section **313**, and to expel the particles **80** toward the trench **31** at and/or along a release trajectory **318** at the particle exit section **314**. For example, the particle belt **84** is configured to rotate, as indicated by arrows **320**, to move the particles **80** from the particle engagement point **310** to the particle exit section **314**. As described in greater detail below, the particle belt **84** is configured to stretch at the particle acceleration section **312** and to retract at the belt retraction section **316**. The particle belt **84** includes a base **322** and flights **324** coupled to and extending from the base **322**. Each pair of opposing flights **324** is configured to receive a respective particle **80** at the particle engagement point **310** and to move the respective particle **80** to the particle exit section **314**.

The particle belt **302** is configured to accelerate the particles **80** received from the particle disc **82**, such that a particle exit speed of each particle **80** expelled from the particle belt **84** along the release trajectory **318** reaches a target particle exit speed (e.g., at the particle exit section **314**). The particle exit speed of each particle **80** may reach the target particle exit speed when the particle exit speed is equal to the target particle exit speed, when the particle exit speed becomes greater than or less than the target particle exit speed, when the particle exit speed is within a threshold range of the target particle exit speed (e.g., a difference between the particle exit speed and the target particle exit speed is less than a threshold value associated with the threshold range), or a combination thereof.

The particle delivery system **300** is configured to accelerate the particles **80** at the particle acceleration section **312** of the particle belt **302**. In the illustrated embodiment, the particle delivery system **40** includes a first hub assembly **340** engaged with the particle belt **302** at a first location **342** (e.g., an interface or a series of interfaces between the first hub assembly **340** and the particle belt **302**) and a second hub assembly **344** engaged with the particle belt **302** at a second location **346** (e.g., an interface or a series of interfaces between the second hub assembly **344** and the particle belt **302**). The first hub assembly **340** is configured to stretch (e.g., gradually stretch) the particle belt **302** at/along the first location **342**, to remain stretch at/along the particle transfer section **313**, and the second hub assembly **344** is configured to retract (e.g., gradually retract/relax) the particle belt **302** at/along the second location **346**, such that the particle belt **302** stretches along the particle acceleration section **312** (e.g., at and/or along the first location **342**), thereby facilitating acceleration of the particles **80** at the particle acceleration section **312**. To enable stretching the particle belt **302** at the particle acceleration section **312** and at the particle transfer section **313**, a substantially no-slip condition exists between the first hub assembly **340** and the particle belt **302** at the first location **342** and between the second hub assembly **344** and the particle belt **302** at the second location **346**. After stretching at the particle acceleration section **312**, the particle belt **302** is configured to retract (e.g., at least partially relax) at the belt retraction section **316** (e.g., at and/or along the second location **346**). The particle belt **302** (e.g., the base **322** and/or the flights **324** of the particle belt **302**) may be formed from an elastic material (e.g., fabric, rubber, plastic, or a combination thereof) configured to stretch and/or retract. As illustrated, the particle transfer section **313** extends generally between the first location **342** and the second location **346** and between the particle acceleration section **312** and the particle exit section **314**. In certain embodiments, the particle transfer section may include at least a portion of the particle acceleration section and/or at least a portion of the particle exit section.

The first hub assembly **340** includes an outer hub **350** (e.g., a first outer hub) and an inner hub **352** (e.g., a first inner hub) disposed eccentrically within the outer hub **350** (e.g., off center relative to the outer hub **350**). The outer hub **350** and the inner hub **352** are configured to rotate, as indicated by arrow **353**. In certain embodiments, the outer hub **350** and the inner hub **352** may rotate at the same rotation rate (e.g., rotations per minute (rpm)). For example, the outer hub **350** and the inner hub **352** may be non-rotatably coupled, such that rotation of the outer hub **350** drives rotation of the inner hub **352**. In certain embodiments, rotation of the inner hub may drive rotation of the outer hub. In some embodiments, motor(s) may drive the inner hub and the outer hub to rotate independently at the same rotation rate.

The first hub assembly **340** includes cogs **354** (e.g., first cogs) coupled to the inner hub **352** and configured to pivot relative to the inner hub **352** as the outer hub **350** and the inner hub **352** rotate. Additionally, the first hub assembly **340** includes guides **356** (e.g., first guides) coupled to and configured to pivot relative to the outer hub **350**. For example, each guide **356** is configured to slide along a respective cog **354** (e.g., each cog **354** extends through a respective guide **356**) and to pivot relative to the outer hub **350** as the outer hub **350** and the inner hub **352** rotate. Each cog **354** is configured to engage the particle belt **302** at the first location **342**, such that rotation of the outer hub **350** and the inner hub **352** and the pivoting of each cog **354** stretch (e.g., gradually stretch) the particle belt **302** at the first location **342**. As described in greater detail below in reference to FIG. **8**, the inner hub **352** disposed eccentrically within the outer hub **350** causes the cogs **354** to stretch the particle belt **302** as the particle belt **302** moves along the first location **342** and as the outer hub **350** and the inner hub **352** rotate, as indicated by arrow **353**.

The second hub assembly **344** includes an outer hub **360** (e.g., a second outer hub) and an inner hub **362** (e.g., a second inner hub) disposed eccentrically within the outer hub **360** (e.g., off center relative to the outer hub **360**). The outer hub **360** and the inner hub **362** are configured to rotate, as indicated by arrow **363**. In certain embodiments, the outer hub **360** and the inner hub **362** may rotate at the same rotation rate (e.g., rotations per minute (rpm)). For example, the outer hub **360** and the inner hub **362** may be non-rotatably coupled, such that rotation of the outer hub **360** drives rotation of the inner hub **362**. In some embodiments, the outer hub **350** of the first hub assembly **340** may be coupled to the outer hub **360** of the second hub assembly **344** via a drive mechanism, such as the drive mechanism of FIG. **4** or the drive mechanism of FIG. **5**, thereby causing rotation of the first hub assembly **340** (e.g., rotation of the outer hub **350**) to drive rotation of the second hub assembly **344** (e.g., rotation of the outer hub **360**). In certain embodiments, rotation of the inner hub may drive rotation of the outer hub. In some embodiments, the inner hub of the first hub assembly may be coupled to the inner hub of the second hub assembly via the drive mechanism, thereby causing rotation of the first hub assembly (e.g., rotation of the inner hub of the first hub assembly) to drive rotation of the second hub assembly (e.g., rotation of the inner hub of the second hub assembly). In certain embodiments, the outer hub and/or the inner hub of the second hub assembly may be driven to rotate by motor(s), which may facilitate independent control of rotation speeds of the first hub assembly and the second hub assembly.

The second hub assembly **344** includes cogs **364** (e.g., second cogs) coupled to the inner hub **362** and configured to pivot relative to the inner hub **362** as the outer hub **360** and the inner hub **362** rotate. Additionally, the second hub assembly **344** includes guides **366** (e.g., second guides) coupled to and configured to pivot relative to the outer hub **360**. For example, each guide **366** is configured to slide along a respective cog **364** (e.g., each cog **364** extends through a respective guide **366**) and to pivot relative to the outer hub **360** as the outer hub **360** and the inner hub **362** rotate. Each cog **364** is configured to engage the particle belt **302** at the second location **346**, such that rotation of the outer hub **360** and the inner hub **362** and the pivoting of each cog **364** retract (e.g., gradually retract and/or gradually relax) the particle belt **302** at the second location **346**. The inner hub **362** disposed eccentrically within the outer hub **360** causes the cogs **364** to retract the particle belt **302** as the particle belt **302** moves along the second location **346** and as the outer hub **360** and the inner hub **362** rotate, as indicated by arrow **363**. In certain embodiments, the second hub assembly may be replaced by a wheel configured to engage the particle belt at the second location via a no-slip condition, such as the second wheel described above in reference to FIG. **3**. Alternatively, the first hub assembly may be replaced by a wheel configured to engage the particle belt at the first location via a no-slip condition, such as the first wheel described above in reference to FIG. **3**.

As illustrated, the particle engagement point **310** of the particle belt **302** is positioned generally at the first location **342** and at the particle acceleration section **312**. In certain embodiments, the particle engagement point may be positioned between the first location and the second location, such that the particle belt is configured to receive the particles at a stretched portion of the particle belt (e.g., at the particle transfer section) or adjacent to the particle retraction section. Additionally, as illustrated, the particle exit section **314** of the particle belt **302** is positioned generally at the second location **346**. In certain embodiments, the particle exit section may be positioned between the first location and the second location.

The first hub assembly **340** and the second hub assembly **344** are configured to rotate to drive rotation of the particle belt **302**. For example, the outer hub **350** and the inner hub **352** of the first hub assembly **340** may drive rotation of the cogs **354**, and the cogs **354** may engage the particle belt **302** at the first location **342**, thereby driving rotation of the particle belt **302**. The outer hub **360** and the inner hub **362** of the second hub assembly **344** may drive rotation of the cogs **364**, and the cogs **364** may engage the particle belt **302** at the second location **346**, thereby driving rotation of the particle belt **302**. At least one of the outer hub **350** of the first hub assembly **340**, the inner hub **352** of the first hub assembly **340**, the outer hub **360** of the second hub assembly **344**, and the inner hub **362** of the second hub assembly **344** may include a pulley or a gear. In certain embodiments, only one of the first hub assembly and the second hub assembly may drive rotation of the particle belt.

The controller **170** is configured to control the belt speed of the particle belt **302** to adjust/control the particle exit speed of the particles **80** expelled from the particle belt **302** (e.g., from the particle exit section **314** of the particle belt **302**, along the release trajectory **318**, and toward the trench **31**), such that the particle exit speed reaches a target particle exit speed. For example, the controller **170** may control the outer hub **350** of the first hub assembly **340**, via the second motor **176** configured to drive rotation of the outer hub **350** and the particle belt **302**, to adjust/control the belt speed of the particle belt **302** (e.g., by outputting an output signal to the second motor **176** indicative of instructions to adjust the rotation rate of the outer hub **350** of the first hub assembly **340**), thereby adjusting/controlling the particle exit speed of the particles **80**. In certain embodiments, the second motor may be configured to drive rotation of the inner hub of the first hub assembly, and the controller may output an output signal to the second motor indicative of instructions to adjust the rotation rate of the inner hub of the first hub assembly. In some embodiments, the second motor may be configured to drive rotation of the outer hub and/or the inner hub of the second hub assembly, and the controller may output an output signal to the second motor indicative of instructions to adjust the rotation rate of the outer hub and/or the inner hub of the second hub assembly. In certain embodiments, the particle delivery system may include a third motor configured to drive rotation of the second hub assembly independent of the first hub assembly.

The controller **170** may control the particle exit speed of the particles **80**, such that the particle exit speed reaches the target particle exit speed. The controller **170** may determine the target particle exit speed of the particles **80** based on the type of the particles **80**, the size of the particles **80**, an input received from a user interface, the ground speed of the row unit, or a combination thereof. The target particle exit speed may be any suitable speed, such one kilometer per hour (kph), two kph, three kph, five kph, ten kph, fifteen kph, twenty kph, etc. In certain embodiments, the controller **170** may determine the target particle exit speed as a target percentage of the ground speed of the row unit (e.g., thirty percent, fifty percent, sixty percent, seventy percent, eighty percent, ninety percent, ninety-five percent, one hundred percent, etc.).

To control the belt speed of the particle belt **302**, the controller **170** may receive an input signal indicative of the particle exit speed of the particle **80** at the particle exit section **314** of the particle belt **302**. For example, the controller **170** may receive the input signal from the particle sensor **178** of the particle delivery system **300** disposed adjacent to the particle exit section **314** and along the release trajectory **318**. The particle sensor **178** may include an infrared sensor or another suitable type of sensor configured to output the input signal indicative of the particle exit speed of each particle **80** at the particle exit section **314**. The particle sensor **178** may be positioned a fixed distance from the particle exit section **314** of the particle belt **302**, such that the controller **170** may determine the particle exit speed of the particle **80** at the particle exit section **314** based on the fixed distance and the input signal indicative of the particle exit speed received from the particle sensor **178** (e.g., based on acceleration and/or deceleration of the particle **80** traveling the fixed distance). In some embodiments, the particle sensor **174** and/or the particle sensor **178** may be omitted from the particle delivery system **300**.

The controller **170** may compare the particle exit speed of the particle **80** at the particle exit section **314** of the particle belt **302** to the target particle exit speed to determine whether a difference between the particle exit speed and the target particle exit speed exceeds a threshold value. In response to determining that the particle exit speed at the particle exit section **314** of the particle belt **302** is less than the target particle exit speed and the difference between the particle exit speed and the target particle exit speed exceeds the threshold value, the controller **170** may output an output signal indicative of instructions to increase the belt speed of the particle belt **302**. For example, the controller **170** may output the output signal to the second motor **176** to cause the second motor **176** to increase the rotation rate of the outer hub **350** of the first hub assembly **340**, thereby increasing the belt speed of the particle belt **302**. The increase in the belt speed of the particle belt **302** may increase the particle exit speed, such that the particle exit speed reaches the target particle exit speed (e.g., such that the difference between the particle exit speed and the target particle exit speed is less than the threshold value).

In response to determining that the particle exit speed at the particle exit section **314** of the particle belt **302** is greater than the target particle exit speed and the difference between the particle exit speed and the target particle exit speed exceeds the threshold value, the controller **170** may output an output signal indicative of instructions to decrease the belt speed of the particle belt **302**. For example, the controller **170** may output the output signal to the second motor **176** to cause the second motor **176** to decrease the rotation rate of the outer hub **350** of the first hub assembly **340**, thereby decreasing the belt speed of the particle belt **302**. The decrease in the belt speed of the particle belt **302** may decrease the particle exit speed, such that the particle exit speed reaches the target particle exit speed (e.g., such that the difference between the particle exit speed and the target particle exit speed is less than the threshold value).

FIG. **8** is a side view of the particle belt **302** and the first hub assembly **340** of the particle delivery system of FIG. **7**. As described above, the outer hub **350** and the inner hub **352** are configured to rotate, as indicated by arrow **353**, to drive rotation of the particle belt **302**. For example, the second motor **176** is configured to drive rotation of the outer hub **350**, thereby driving rotation of the first hub assembly **340** and the particle belt **302**. Additionally, a substantially no-slip condition exists between the particle belt **302** and the first hub assembly **340** at the first location **342** and between the particle belt **302** and the second hub assembly at the second location. The substantially no-slip conditions enable the first hub assembly **340** and the second hub assembly to stretch the particle belt **302** at/along the particle acceleration section **312**, thereby accelerating the particles **80** at/along the particle acceleration section **312**.

The particle belt **84** has recesses **380** formed along the base **322** and configured to receive the cogs **354** of the first hub assembly **340**. The interface between the cogs **354** and the recesses **380** (e.g., the cogs **354** extending into the recesses **380**) provides the no-slip condition at the first location **342**. For example, as the first hub assembly **340** rotates, as indicated by arrow **353**, the cogs **354** may rotate/move at the same speed as the particle belt **302**. As illustrated, each cog **354** includes a member **382** and arms **384** (e.g., two arms **384**) extending from the member **382**. The member **382** is coupled to the inner hub **352** and is configured to extend into a respective recess **380** of the base **322** of the particle belt **302**, and each arm **384** is configured to abut a rear surface **386** of the base **322** of the particle belt **302**.

As the outer hub **350** and the inner hub **352** rotate, as indicated by arrow **353**, the first hub assembly **340** gradually stretches the particle belt **302**. For example, the cogs **354** first engage the particle belt **302** at a first area **390** of the first location **342**. As the outer hub **350** and the inner hub **352** rotate, the cogs **354** rotate from the first area **390** of the first location **342** to a second area **392** of the first location **342**. Because the inner hub **352** is disposed eccentrically within the outer hub **350**, a spacing between adjacent cogs **354** (e.g., between the arms **384** of adjacent cogs **354**) increases, and the cogs **354** accelerate as the cogs **354** rotate from the first area **390** toward the second area **392**. The increased spacing between the cogs **354** causes the particle belt **302** to gradually stretch as the particle belt **302** rotates, thereby accelerating the particles **80**. As illustrated, the particle engagement point **310** is disposed generally between the first area **390** and the second area **392**. In certain embodiments, the particle engagement point **310** may be disposed at the first area **390**, at the second area **392**, or at a third area **394** of the particle belt **302** prior to the first area **390** (e.g., a retracted portion of the particle belt **302**).

As described above, the second hub assembly of the particle delivery system is configured to gradually retract the particle belt as the particle belt moves along the second hub assembly. For example, the cogs of the second hub assembly may first engage the recesses of the particle belt at a first area of the second location and may rotate toward a second area of the second location (e.g., via rotation of the outer hub and the inner hub of the second hub assembly). As the outer hub and the inner hub of the second hub assembly rotate, a spacing between the adjacent cogs may gradually decrease due to the inner hub being disposed eccentrically within the outer hub, thereby gradually retracting the particle belt as the particle belt moves along the second hub assembly (e.g., from the first area of the second location toward the second area of the second location).

FIG. **9** is a flow diagram of an embodiment of a process **400** for controlling a particle delivery system. The process **400**, or portions thereof, may be performed by the controller of the particle delivery system. The process **400** begins at block **402**, in which an input signal indicative of operating parameter(s) is received. For example, the operating parameters may include the type of the particles, the ground speed of the row unit, a spacing between the flights the particle belt, the size of the particles, or a combination thereof. The input signal may be received from the user interface communicatively coupled to the controller, may be stored in the memory of the controller, may be received via sensor(s) of the row unit and/or the agricultural implement, may be received from a transceiver, or a combination thereof.

At block **404**, the target particle transfer speed is determined. For example, the controller may determine the target particle transfer speed of the particles based on the type of the particles, the belt speed of the particle belt (e.g., the particle belt having the particle engagement section/point configured to receive the particles traveling at the particle transfer speed), the spacing between flights of the particle belt, the size of the particles, and/or other operating parameters. At block **406**, an input signal indicative of the particle transfer speed of the particle at the particle engagement section/point of the particle belt is received. For example, the controller may receive the input signal indicative of the particle transfer speed from the particle sensor disposed proximate to the particle engagement section/point. In certain embodiments, the controller may receive multiple input signals from the particle sensor, in which each input signal is indicative of a particle transfer speed of a respective particle. The controller may determine an average of the multiple particle transfer speeds to determine the average particle transfer speed of the particles at the particle engagement section/point. As such, the controller may account for variance among the particle transfer speeds of multiple particles at the particle engagement section/point to reduce excessive control actions (e.g., adjustments to the flow rate of the air flow provided by the air flow system).

At block **408**, a determination of whether a difference between the particle transfer speed and the target particle transfer speed exceeds a threshold value is made (e.g., by the controller). Additionally, a determination of whether the particle transfer speed is less than or greater than the target particle transfer speed is made (e.g., by the controller). The threshold value may be determined based on the type of the particles and/or the belt speed of the particle belt. In response to the difference exceeding the threshold, the process **400** proceeds to block **410**. In response to the difference not exceeding the threshold, the process **400** returns to block **406** and receives the next input signal indicative of the particle transfer speed.

At block **410**, in response to the difference between the particle transfer speed and the target particle transfer speed exceeding the threshold value, an output signal indicative of instructions to adjust the flow rate of the air flow provided by the air flow system is output by the controller. For example, the controller may output the output signal indicative of instructions to increase the flow rate of the air flow provided by the air flow system in response to a determination that the particle transfer speed is less than the target particle transfer speed and the difference between the particle transfer speed and the target particle transfer speed exceeds the threshold value, or the controller may output the output signal indicative of instructions to decrease the flow rate of the air flow provided by the air flow system in response to a determination that the particle transfer speed is greater than the target particle transfer speed and the difference between the particle transfer speed and the target particle transfer speed exceeds the threshold value.

After completing block **410**, the process **400** returns to block **406** and receives the next input signal indicative of the particle transfer speed of the particle at the particle engagement section/point of the particle belt. The next determination is made of whether the difference between the particle transfer speed and the target particle transfer speed exceeds the threshold value (e.g., block **408**), and the flow rate of the air flow may be adjusted in response to the determination. As such, blocks **406-410** of the process **400** may be iteratively performed (e.g., by the controller of the particle delivery system and/or by another suitable controller) to facilitate acceleration of the particles to the target particle transfer speed and transfer of the particles from the particle disc to the particle belt. In some embodiments, certain blocks of the blocks **402-410** may be omitted from the process **400**, and/or the order of the blocks **402-410** may be different.

FIG. **10** is a flow diagram of an embodiment of a process **420** for controlling a particle delivery system. The process **420**, or portions thereof, may be performed by the controller of the particle delivery system. The process **420** begins at block **422**, in which an input signal indicative of operating parameter(s) is received. For example, the operating parameters may include the type of the particles, the ground speed of the row unit, a spacing between flights of one or more particle belts, a size of the particles, or a combination thereof. The input signal may be received from the user interface communicatively coupled to the controller, may be stored in the memory of the controller, may be received via sensor(s) of the row unit and/or the agricultural implement, may be received from a transceiver, or a combination thereof.

At block **424**, the target particle exit speed is determined. For example, the controller may determine the target particle exit speed of the particles based on the type of the particles, the ground speed of the row unit, the size of the particles, and/or other operating parameters. At block **426**, an input signal indicative of the particle exit speed of the particle at the particle exit section of the particle belt is received. For example, the controller may receive the input signal indicative of the particle exit speed from the particle sensor disposed proximate to the particle exit section of the particle belt. In certain embodiments, the controller may receive multiple input signals from the particle sensor, in which each input signal is indicative of a particle exit speed of a respective particle. The controller may determine an average of the multiple particle exit speeds to determine the average particle exit speed of the particles at the particle exit section. As such, the controller may account for variance among the particle exit speeds of multiple particles at the particle exit section to reduce excessive control actions (e.g., adjustments to the belt speed of the particle belt).

At block **428**, a determination of whether a difference between the particle exit speed and the target particle exit speed exceeds a threshold value is made (e.g., by the controller). Additionally, a determination of whether the particle exit speed is less than or greater than the target particle exit speed is made (e.g., by the controller). The threshold value may be determined based on the type of the particles, the ground speed of the row unit, and/or other factors. In response to the difference exceeding the threshold, the process **420** proceeds to block **430**. In response to the difference not exceeding the threshold, the process **420** returns to block **426** and receives the next input signal indicative of the particle exit speed.

At block **430**, in response to the difference between the particle exit speed and the target particle exit speed exceeding the threshold value, an output signal indicative of instructions to adjust the belt speed of the particle belt is output to the motor configured to drive rotation of the particle belt (e.g., the motor configured to drive rotation of the wheel coupled to and configured to drive rotation of the particle belt and/or the hub assembly coupled to and configured to drive rotation of the particle belt). For example, the controller may output the output signal indicative of instructions to increase the belt speed of the particle belt in response to a determination that the particle exit speed is less than the target particle exit speed and the difference between the particle exit speed and the target particle exit speed exceeds the threshold value. Further, the controller may output the output signal indicative of instructions to decrease the belt speed of the particle belt in response to a determination that the particle exit speed is greater than the target particle exit speed and the difference between the particle exit speed and the target particle exit speed exceeds the threshold value.

After completing block **430**, the process **420** returns to block **426** and receives the next input signal indicative of the particle exit speed of the particle at the particle exit section of the particle belt. The next determination is made of whether the difference between the particle exit speed and the target particle exit speed exceeds the threshold value (e.g., block **428**), and the belt speed of the particle belt may be adjusted in response to the determination. As such, blocks **426-430** of the process **420** may be iteratively performed (e.g., by the controller of the particle delivery system and/or by another suitable controller) to facilitate acceleration of the particles to the target particle exit speed. In some embodiments, certain blocks of the blocks **422-430** may be omitted from the process **420**, and/or the order of the blocks **422-430** may be different.

Embodiments of a particle delivery system described herein may facilitate deposition of particles into a trench in soil. The particle delivery system may be configured to accelerate the particles downwardly toward the trench and to provide particular spacings between the particles along the trench. For example, the particle delivery system may include a particle disc configured to meter individual particles, thereby establishing a particular spacing between particles. The particle disc may be configured to release the particles from a release point of the particle disc. A particle belt of the particle delivery system may be configured to receive the particles from the particle disc and to expel the particles toward the trench in the soil. In certain embodiments, a particle acceleration section of the particle belt may be stretched, such that a particle exit speed of the particles exiting a particle exit section of the particle belt reaches a target particle exit speed (e.g., after the particles pass through the particle acceleration section and are expelled from the particle belt at the particle exit section). The particle belt may accelerate the particles to a speed greater than a speed resulting from gravitational acceleration alone. As such, the particle delivery system may enable the row unit to travel faster than traditional row units that utilize seed tubes, which rely on gravity to accelerate the particles (e.g., seeds) for delivery to soil. Additionally, the particle belt may accelerate the particles such that the particle delivery system reduces the relative ground speed of the particles, thereby enabling the particle delivery system to accurately deposit the particles within the trench in soil.

In certain embodiments, the particle delivery system may include wheel(s) engaged with the particle belt and configured to rotate at different rotational speeds to stretch the particle belt at the particle acceleration section and to accelerate the particles. For example, the wheels may be engaged with the particle belt, and a substantially no-slip condition may exist between each wheel and the particle belt. In some embodiments, the particle delivery system may include hub assembly(ies) engaged with the particle belt and configured to stretch the particle belt at the particle acceleration section to accelerate the particles. For example, the hub assemblies may be engaged with the particle belt, and a substantially no-slip condition may exist between each hub assembly and the particle belt. Each hub assembly may include an outer hub configured to rotate, an inner hub disposed eccentrically within the outer hub and configured to rotate with the outer hub, cogs coupled to the inner hub and configured to pivot relative to the inner hub as the inner hub and the outer hub rotate, and guides coupled to respective cogs and to the outer hub. Each guide may be configured to slide along the respective cog and along the outer hub as the inner hub and the outer hub rotate, and each cog may be configured to engage the particle belt, such that the rotation of the inner hub and the outer hub and the pivoting of each cog stretches the particle belt.

Additionally, features of certain embodiments of the particle delivery systems described herein may be combined with features of other embodiments. For example, the first wheel and/or the second wheel of FIGS. **3-5** may be included in the particle delivery system of FIG. **6**. In certain embodiments, the first wheel and/or the second wheel of FIG. **6** may be included in the particle delivery system of FIG. **3**. In some embodiments, the first wheel and/or the second wheel of FIGS. **3-6** may be included in the particle delivery system of FIGS. **7** and **8**. In certain embodiments, the belt tension assembly of FIG. **3** may be included in the particle delivery system of FIG. **7**. In some embodiments, the drive mechanism(s) of FIGS. **5** and/or **6** may be included in the particle delivery system of FIG. **7**. In certain embodiments, the first hub assembly and/or the second hub assembly of FIGS. **7** and **8** may be included in the particle delivery system of FIG. **3**. Additionally or alternatively, the embodiments of the particle delivery systems described herein, or portions thereof, may be combined in other suitable manners.

The techniques presented and claimed herein are referenced and applied to material objects and concrete examples of a practical nature that demonstrably improve the present technical field and, as such, are not abstract, intangible or purely theoretical. Further, if any claims appended to the end of this specification contain one or more elements designated as "means for [perform]ing [a function] . . . " or "step for [perform]ing [a function] . . . ", it is intended that such elements are to be interpreted under 35 U.S.C. 112(f). However, for any claims containing elements designated in any other manner, it is intended that such elements are not to be interpreted under 35 U.S.C. 112(f).

While only certain features of the disclosure have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the disclosure.

The invention claimed is:

1. A particle delivery system of an agricultural row unit, comprising:

a particle belt having a particle acceleration section, wherein the particle belt is configured to receive a particle from a particle metering and singulation unit, to accelerate the particle at the particle acceleration section, and to expel the particle toward a trench in soil;

a first hub assembly engaged with the particle belt at a first location; and

a second hub assembly engaged with the particle belt at a second location, wherein the particle acceleration section is disposed generally at the first location, a substantially no-slip condition exists between the first hub assembly and the particle belt at the first location and between the second hub assembly and the particle belt at the second location, and the first hub assembly and the second hub assembly are configured to stretch the particle belt at the particle acceleration section to accelerate the particle at the particle acceleration section.

2. The particle delivery system of claim **1**, wherein the first hub assembly is configured to stretch the particle belt at the first location, and the second hub assembly is configured to retract the particle belt at the second location, such that the first hub assembly and the second hub assembly stretch the particle belt along the particle acceleration section.

3. The particle delivery system of claim **1**, wherein the first hub assembly comprises an outer hub configured to rotate, an inner hub disposed eccentrically within the outer hub and configured to rotate with the outer hub, a plurality of cogs coupled to the inner hub and configured to pivot relative to the inner hub, and a plurality of guides coupled to the outer hub and configured to pivot relative to the outer hub;

wherein each guide of the plurality of guides is configured to slide along a respective cog of the plurality of cogs, and the plurality of cogs are configured to engage the particle belt at the first location, such that the rotation of the inner hub, the rotation of the outer hub, and the pivoting of the plurality of cogs stretch the particle belt at the first location.

4. The particle delivery system of claim **3**, wherein the inner hub is non-rotatably coupled to the outer hub.

5. The particle delivery system of claim **3**, wherein at least one of the inner hub and the outer hub comprises a pulley or a gear.

6. The particle delivery system of claim **3**, wherein the particle belt comprises a base and a plurality of flights extending from the base, and each pair of opposing flights of the plurality of flights is configured to receive the particle from the particle metering and singulation unit.

7. The particle delivery system of claim **6**, wherein the base has a plurality of recesses, and each recess of the plurality of recesses is configured to receive a respective cog of the plurality of cogs to establish the substantially no-slip condition between the first hub assembly and the particle belt at the first location.

8. The particle delivery system of claim **6**, wherein the base of the particle belt is formed from an elastic material configured to stretch, retract, or both.

9. The particle delivery system of claim **1**, wherein the first hub assembly and the second hub assembly are configured to drive rotation of the particle belt.

10. The particle delivery system of claim **1**, wherein the particle belt has a belt retraction section disposed generally at the second location and generally opposite the particle acceleration section, and the particle belt is configured to retract at the belt retraction section.

11. A particle delivery system of an agricultural row unit, comprising:

a particle metering and singulation unit configured to meter a plurality of particles from a particle storage area;

a particle belt having a particle acceleration section, wherein the particle belt is configured to receive the plurality of particles from the particle metering and singulation unit, to accelerate the plurality of particles at the particle acceleration section, and to expel the plurality of particles toward a trench in soil;

a first hub assembly engaged with the particle belt at a first location; and

a second hub assembly engaged with the particle belt at a second location, wherein the particle acceleration section is disposed generally at the first location, a substantially no-slip condition exists between the first hub assembly and the particle belt at the first location and between the second hub assembly and the particle belt at the second location, and the first hub assembly and the second hub assembly are configured to stretch the particle belt at the particle acceleration section to accelerate the particle at the particle acceleration section.

12. The particle delivery system of claim **11**, wherein the first hub assembly comprises an outer hub configured to rotate, an inner hub disposed eccentrically within the outer hub and configured to rotate with the outer hub, a plurality of cogs coupled to the inner hub and configured to pivot relative to the inner hub, and a plurality of guides coupled to the outer hub and configured to pivot relative to the outer hub;

wherein each guide of the plurality of guides is configured to slide along a respective cog of the plurality of cogs, and the plurality of cogs are configured to engage the particle belt at the first location, such that the rotation of the inner hub, the rotation of the outer hub, and the pivoting of the plurality of cogs stretch the particle belt at the first location.

13. The particle delivery system of claim **12**, wherein the particle belt comprises a base and a plurality of flights extending from the base, and each pair of opposing flights of the plurality of flights is configured to receive the particle from the particle metering and singulation unit.

14. The particle delivery system of claim **13**, wherein the base has a plurality of recesses, and each recess of the plurality of recesses is configured to receive a respective cog of the plurality of cogs to establish the substantially no-slip condition between the first hub assembly and the particle belt at the first location.

15. The particle delivery system of claim **11**, wherein the particle metering and singulation unit comprises a disc configured to extract each particle of the plurality of particles from the particle storage area, rotate the particle, and deposit the particle at a position generally above the particle belt.

16. A particle delivery system of an agricultural row unit, comprising:

a particle belt having a particle acceleration section and a particle exit section, wherein the particle belt is configured to receive a particle from a particle metering and singulation unit, to accelerate the particle at the particle acceleration section, and to expel the particle toward a trench in soil at the particle exit section;

a first hub assembly engaged with the particle belt at a first location;

a second hub assembly engaged with the particle belt at a second location, wherein the particle acceleration section is disposed generally at the first location, a substantially no-slip condition exists between the first hub assembly and the particle belt at the first location and between the second hub assembly and the particle belt at the second location, and the first hub assembly and the second hub assembly are configured to stretch the particle belt at the particle acceleration section to accelerate the particle at the particle acceleration section; and

a controller comprising a memory and a processor, wherein the controller is configured to:

receive an input signal indicative of a particle exit speed of the particle at the particle exit section of the particle belt; and

output an output signal indicative of instructions to adjust a belt speed of the particle belt, such that a difference between the particle exit speed and a target particle exit speed is less than a threshold value.

17. The particle delivery system of claim **16**, wherein the controller is configured to output the output signal indicative of instructions to increase the belt speed of the particle belt in response to determining that the particle exit speed is less than the target particle exit speed and the difference between the particle exit speed and the target particle exit speed exceeds the threshold value.

18. The particle delivery system of claim **16**, wherein the controller is configured to output the output signal indicative of instructions to decrease the belt speed of the particle belt in response to determining that the particle exit speed is greater than the target particle exit speed and the difference between the particle exit speed and the target particle exit speed exceeds the threshold value.

19. The particle delivery system of claim **16**, wherein the controller is configured to determine the target particle exit speed based on a type of the particle, a size of the particle, a ground speed of the agricultural row unit, or a combination thereof.

20. The particle delivery system of claim **16**, wherein the first hub assembly comprises an outer hub configured to rotate, an inner hub disposed eccentrically within the outer hub and non-rotatably coupled to the outer hub, a plurality of cogs coupled to the inner hub and configured to pivot relative to the inner hub, and a plurality of guides coupled to the outer hub and configured to pivot relative to the outer hub;

wherein each guide of the plurality of guides is configured to slide along a respective cog of the plurality of cogs, and the plurality of cogs are configured to engage the particle belt at the first location, such that the rotation of the inner hub and the pivoting of the plurality of cogs stretch the particle belt at the first location.

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